The Engineer

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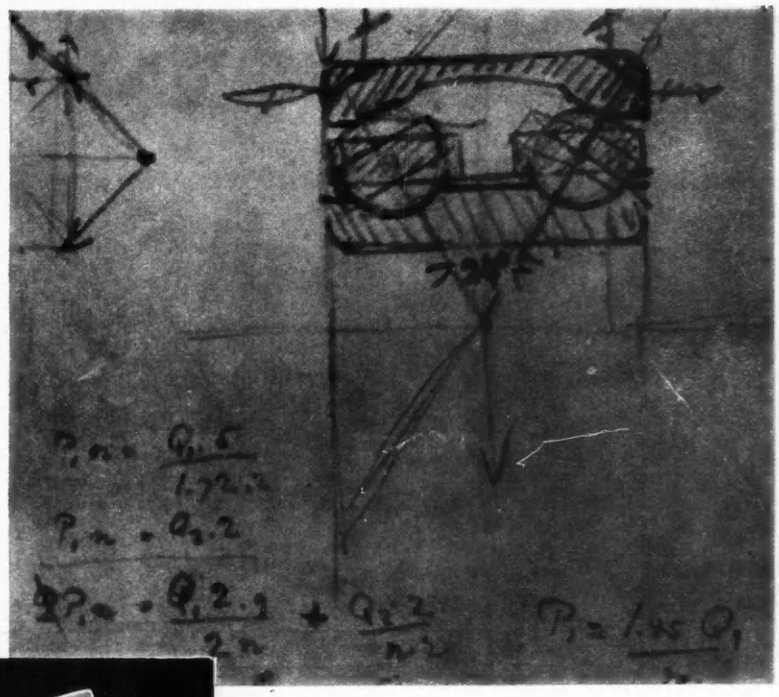
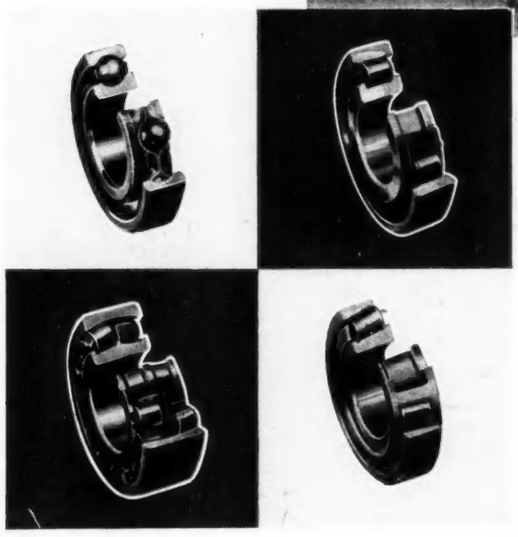


A reproduction of the first rough sketch of the double row self-aligning ball bearing, invented by Dr. Sven Wingquist the founder of **SKF**.



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The 34″ Blooming Mill

Photograph by courtesy of Llanelly Steel Co. (1907) Ltd.

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THE ENGINEER

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ESTIMATES FOR THE FIGHTING SERVICES

The policy outlined for the next five years in the Defence White Paper, 1957, may be fittingly described as "*reculer pour mieux sauter*" and the Estimates for all three Services leave no doubt that it is already being implemented. Besides the further substantial reduction in manpower—eventually to be reduced from the present figure of 690,000 to 375,000—savings are being made in all directions to pay for the expensive missile systems and other weapons of the future. Research and development programmes are being revised, non-essential establishments closed down and maintenance costs reduced by running down the level of reserves of material. The net amount asked for the Navy is £316 million, or nearly £33,000,000 less than the revised Estimates for last year—a reduction even more drastic than appears if allowance is made for higher costs. Cuts in the Senior Service are, however, the inevitable outcome of the new policy of trying to prevent war rather than to prepare for it. Despite the First Lord's confident assertion that the Navy is prepared for all forms of war, its main purpose is in future to bring power rapidly to bear in peacetime emergencies or limited hostilities. It has no present deterrent value and our 200 modern minesweepers and substantial force of anti-submarine vessels would only be required in total war if we manage to survive thermo-nuclear attack—a possibility which the Government clearly does not anticipate.

The active fleet is to consist of a small number of carrier groups, each composed of one carrier with its supporting ships. There is still no information of the completion of the "Hermes," but the reconstructed and modernised "Victorious" should be ready for service at the end of this year. With these two ships we shall have seven fast modern carriers—enough to provide five carrier groups in active commission, including one in the Indian Ocean. Nineteen cruisers are at present available to act as supporting ships, but in another five years seventeen of them will be twenty years old or older. It seems doubtful whether we shall by then have more than a dozen cruisers in service, including the three "Tiger" class ships now completing. This number would barely provide two cruisers for each carrier group. Other supporting ships would, of course, include the eight "Daring" class ships and also the four new fleet escort vessels which have been ordered and are to be equipped with the "Sea-Slug" guided missile. The "Vanguard"—the most powerful unit of the Royal Navy—happily still remains. The other four battleships are to be scrapped this year.

The net expenditure on the Army is estimated at £401,400,000—a saving of over £98,500,000 on last year. The saving has been mainly achieved by reducing the strength of British Army units stationed overseas; by cancelling orders for equipment; by the maximum use of existing stocks and by restricting part-time training in the Reserve Army to volunteers. A central reserve has been reconstituted in the United Kingdom, organised for limited or global war, with units on a brigade basis specially trained for internal security duties. A second surface-to-surface guided weapon regiment is being formed and both regiments will be equipped with the American "Corporal." The F.N. rifle has fully come up to expectations and United Kingdom production is to start this year. Other new weapons and equipment are a sub-machine gun to replace the Sten gun, a replacement for the Vickers machine gun and a new combat equipment. The utmost priority is being given to the Army's living accommodation and the present unsatisfactory combination of enlistment terms is under review.

The net total of the Air Estimates at £487,650,000 shows an apparent increase of more than £10,000,000 on last year, but with the variation in receipts from the United States and Germany the true comparison is in fact a reduction of nearly £19,000,000. A noteworthy feature is the reliance which is to be placed on the V-bomber as the foundation of our deterrent for many years to come. Later marks are to be equipped to carry an air-to-surface guided flying bomb for launching outside hostile air defence and eventually outside radar range. It is indeed clear that little thought has yet been given to the ballistic rockets to be received from the United States. They are still in the prototype stage and each Service in that country is developing its own version—the Air Force, the "Thor"; the Army, the "Jupiter"; and the Navy, the "Polaris"—all with an anticipated range of 1500 miles. The Navy is going full speed ahead with the "Polaris"—two merchant ships are now being converted for prototype launchings—but the Army

objects strongly to the directive from the Secretary of Defence that further development of the "Jupiter" is to cease by January 1, 1958. It is to be hoped that we shall not have these inter-Service arguments in this country and that missiles which could not otherwise reach vital targets in Russia will be made a naval responsibility. Progress in anti-aircraft defence is encouraging. A production order has been given for the supersonic P.1; acceptance trials of the new air-to-air de Havilland "Firestreak" are to begin shortly, and the first R.A.F. guided missile station, to launch Britain's first ground-to-air missile, the Bristol/Ferranti "Blood-hound," is to come into service in 1958.

SCIENCE IN SCHOOLS

Towards the end of 1955, several companies engaged in chemical, electrical and mechanical engineering, together considered what further steps they could take whereby more boys and girls still at school might be encouraged to turn to careers in science and technology. The outcome of their investigations and deliberations was the establishment of the Industrial Fund for the Advancement of Scientific Education in Schools. The advice taken by the executive committee appointed to administer the fund indicated that the universities and technical colleges of this country would eventually be able to offer more places to potential scientists and technologists than the schools of this country would be able to fill. At the outset, it was decided that the fund should be concentrated upon independent and direct grant schools, these, of course, being the schools which cannot obtain assistance from public funds for any capital works they wish to carry out. These schools, it was therefore agreed, should be given financial assistance for the building, modernisation and equipment of science laboratories.

The second report on the fund has just been published. It records that 141 industrial companies have subscribed over £3,000,000, most of which money has now been committed by way of grants for building and for scientific apparatus. Building grants to 187 schools have been approved, and ninety-two of the buildings are expected to be completed this year. In addition, 328 schools have been offered grants for scientific apparatus. Before any of the grants were decided upon, visits to the various schools were made by assessors appointed by the committee administering the fund. The report of these assessors is revealing. It shows, for example, that while a year ago the number of boys reading science at independent and direct grant schools was three times as great as in 1935, they were being taught in accommodation that had scarcely been increased in any way. The operation of this "Industrial Fund" has undoubtedly stimulated both thought and action in the schools and has also done much to encourage science teachers. The long-term effect cannot fail to be of help to industry. But there are some other beneficial factors. It has for long been realised that too few science graduates take up teaching, and in this matter the fund may well confer a two-fold benefit. An increase in the number of sixth-form science students will produce more graduates suitable for recruitment to the teaching profession and, through improved conditions for work in schools, it can confidently be hoped that more graduates will find the prospect of science teaching attractive. The contributors to and administrators of this fund have already demonstrated one more practical way in which industry is assisting the future of science and technology in this country. The assessors describe the Industrial Fund for the Advancement of Scientific Education in Schools as a "unique experiment." It is an experiment which deserves the success that it is already achieving.

NOT A BRITISH INDUSTRIES FAIR

It is, of course, unkind when the Birmingham section of the British Industries Fair has only, since last year, come under new management, to prove critical of this year's engineering exhibits at Castle Bromwich. But no engineer who has made a visit to Castle Bromwich this year could possibly have come away without feeling critical; and we hope the Birmingham Chamber of Commerce will accept what we have to say as an attempt to be constructive rather than destructive. Right away out in front, of course, the remark must be made that supposing the Fair is to continue to be held annually it has now become essential to change its title. Even when there were sections of the Fair in London covering other industries than hardware and engineering the title British Industries Fair was a wild overstatement. The Fair never did adequately represent British industry, even in the days between the wars, when it was much more fully supported by engineering firms than it is now. But to-day, confined as it is to engineering and hardware, it has become grossly deceptive, particularly to overseas visitors, to suggest any comparison with the great national and representative exhibitions held at various centres on the Continent, notably at Hanover. What is still entitled the British Industries Fair has become merely a mixed hardware and engineering exhibition.

The other question that must be asked is whether or not the attempt to maintain the engineering side of the Fair should be continued. In fact, this year, as indeed for many years past, the engineering section of the Fair has been very far from representative of British engineering. Heavy engineering firms have been conspicuous by their absence and the trend towards the holding in London of specialised sectional exhibitions has drawn away from this Birmingham Fair many firms that formerly were accustomed to exhibit there. The consequence is that the engineering section of the B.I.F. is not only unrepresentative of major sections of the British engineering industry, but also lacking any kind of character at all. No one visiting the Fair can feel at all sure what kind of exhibits he will see; whereas at the London specialised exhibitions he does know, and knows moreover that there is a high probability that competing firms in whose products he is particularly interested will all have taken space. But at Castle Bromwich there is only an amorphous collection of exhibits. Finding certain products on one stand, the visitor may look in vain for the competing similar products of other firms. If the engineering section of the Fair is to continue to attract exhibitors the organisers will need somehow to give a peculiar character to the Fair distinguishing it from all other exhibitions.

What then is to be done with the Fair? There is talk of making it international. But in the engineering sense we confess to a feeling that its attractions will be nil for foreign exhibitors. If, however, the Fair was confined to hardware, including domestic products—the hardware section appears to be far more satisfactory than the engineering section—and perhaps to industries ancillary to the production of hardware; and if the organisers were careful quite rigidly to exclude firms not coming within those categories, a Fair with a character of its own might be created. The outdoor section is already tending to become associated with the building, though no longer with the civil constructing, industry and that trend might be encouraged. On these lines a truly international reputation might be built up. It has, however, to be remembered that a Hardware Trades Fair is already held in London. Alternatively, the need to give a peculiar character to the Fair—for lacking a character peculiar to itself it can never hope for success—might be met by restricting it to exhibits from Birmingham and the Midlands. Whatever the outcome, however, the Fair should cease to bear its present title. To accept a change of title and to restrict the nature of the Fair sufficiently to give it character must be to fall very far below the intentions of those who originally conceived it. But, in fact, the industries of Britain are so enormously varied that upon no site of reasonable size could there be adequate trade representation of them all, simultaneously. A truly representative British Industries Fair is not a practicable proposition.

A Seven Day Journal

The Royal Ordnance Factories

THE MINISTER OF SUPPLY, Mr. Aubrey Jones, last week met trade union officials and representatives from each of the Royal Ordnance Factories to discuss the future of these factories in the light of the recent White Paper on Defence. The Minister explained that the factories existed first of all to meet the current needs of the Forces and to provide an emergency reserve of arms-making capacity. Until recently the emergency in mind was a major war lasting several years, but now, if a major conflict were to break out, it would be devastating and short, and there would be no question of massive war-time production increases.

The Minister went on to say that the ordnance factories must be the preferred source of production for the munitions they were equipped to produce, though he wished to see them extend more into the field of the newer weapons. The factories already had orders for rocket launchers and components, and he hoped that eventually they could undertake electronic repair work. Nevertheless, lacking basic facilities for design and development, and the right sort of manufacturing equipment, the ordnance factories could not become large-scale producers of guided weapons without extensive and costly re-equipment. Such action would merely duplicate capacity already existing in the aircraft and electronics industries and would be a costly way of maintaining ordnance factory employment at the expense of unemployment elsewhere. Mr. Jones added that where ordnance factories, which had to be kept in being for defence production, were not fully employed, it was reasonable for them to undertake civil work in order to maintain a proper labour nucleus. They could also undertake orders for civil work when capacity in private industry was already being fully used. In the light of the fundamental changes which had taken place in strategic conceptions, there was bound to arise considerable surplus capacity in the ordnance factories over the next two or three years. He was anxious to ensure that adaption to the new lower level of capacity should take place as quickly as possible, though he was not yet in a position to name the factories that would have to be closed.

Reactor Technology Training

THE United Kingdom Atomic Energy Authority has stated that the next reactor technology courses for senior technical executives will be held at the Reactor School, Atomic Energy Research Establishment, Harwell, from October 21 to 31, and from January 6 to 16, 1958. These will be the first such courses for senior executives open to overseas as well as British students. The courses are planned to give to senior industrialists with a technical background an overall appreciation of the problems of reactor technology. The lectures cover the physical, metallurgical and engineering problems involved in the design of power reactors and the chemical problems of fuel and effluent processing. There will also be lectures on the United Kingdom's nuclear power programme and on the organisation of the United Kingdom Atomic Energy Authority and its relations with industry. Informal detailed discussion of particular points will be encouraged. There will be visits to laboratories and reactors within the Establishment.

Need for New Roads

THE British Road Federation held its annual general meeting in London last Wednesday, during the course of which the Federation's chairman, Lord Derwent, made a speech in which he commented upon the present situation on the roads, and the Government's road policy. The Federation had campaigned for modern roads for ten years, he pointed out, and the first stretch of motorway—the Preston By-pass—would be open for traffic next year. By British Government standards there were a few encouraging signs in the road-building world, but there were also signs of what happened when a nation neglected its roads. These Lord Derwent referred to as traffic necrosis, a disease meaning "dead in parts," which showed itself as black spots. He went on to quote figures from European economic surveys which showed how little this country planned to spend on roads compared with other European countries, and figures of investment in other industries in this country, all of which were greatly in excess of investments in roads. Loans were the best method of financing new road works, Lord Derwent asserted, and if an issue were made for that purpose in the City tomorrow, he went on, it would be taken up in a matter of hours. The challenge needed meeting with vision and energy, Lord Derwent affirmed, not the Lilliputian thinking which merely fiddled with the country's traffic tangles by devising petty restrictions to make traffic fit roads and streets never intended for to-day's needs.

The Engineer
100 Years Ago
(MAY 15, 1857)

"STRIKE OF OMNIBUS SERVANTS"

"Some excitement has been created in the north-western and western districts of the metropolis by the parading to and fro during the day of from 200 to 300 rough-looking men—half-ostler and half-cad—who declared themselves to be the servants of the London General Omnibus Company 'on strike,' and have been going about to the stables of the company in the different district establishments, calling upon their brethren to join with them in throwing themselves out of work. The omnibuses of the company are 600 in number, and every omnibus having ten horses, each vehicle is placed separately under the care of a horse-keeper, whose business it is to deliver them over in good order every morning to the driver and conductor. The class of men employed as horsekeepers are, of course, rough and uneducated, and the company found on purchasing the various 'yards' and establishments that also, as a matter of course, they were receiving low wages, averaging from 16s. to 18s. weekly, while those wages were made up by a mutual agreement, which generally led to the extra sum paid by coachman and conductor to the horsekeeper being levied on the employer. . . .

"When the large system of the London General Omnibus Company, with 600 vehicles and 6000 horses, comprehended also 2000 persons connected with them, order and discipline were necessary; and these were at once introduced, on the railway system, by Mr. Church, the secretary. Hence, the 'strike' of Sunday, which, though expected a fortnight since, nevertheless took the district surveyors and officers of the company by surprise. . . . Immediate measures have been taken by the company to furnish themselves with new horsekeepers. . . . Hitherto these men have conducted themselves peaceably, but the directors of the London General Omnibus Company have passed a resolution not to receive any of them into their employment again, it being necessary at once to put down a system of combination which might end some day, if encouraged, in leaving the metropolis totally without vehicle accommodation."

Blackwall Tunnel Improvement

THE Minister of Transport and Civil Aviation, Mr. Harold Watkinson, has made a grant of nearly £1,000,000 to the London County Council towards the cost of improving the northern approach to the Blackwall Tunnel under the Thames. The scheme provides for a two-level layout, incorporating a half-clover leaf design to allow the uninterrupted flow of traffic into and out of the tunnel as well as along the East India Dock Road. At present the Northern Approach forms a single-level right-angle junction with the East India Dock Road, which carries 21,000 vehicles a day. Traffic through the tunnel amounts to 11,000 vehicles a day and the junction—one of the busiest in London—is therefore very congested.

The cutting from the tunnel entrance will be extended to a point north of the East India Dock Road and the East India Dock Road carried over it on a new bridge. The scheme has been designed to accommodate the entrance to a second tunnel, which it is intended to build at some future date. The work will be carried out by contract under the direction of the chief engineer of the London County Council, Mr. J. Rawlinson, C.B.E., M.I.C.E. Contract drawings are now well advanced, we are informed, so that the L.C.C. will be able to invite tenders and begin road works later this year.

Lanchester Memorial Lecture

ON Thursday of last week the first Lanchester Memorial Lecture was delivered to the Royal Aeronautical Society by Dr. Theodore von Kármán. Concentrating on the contributions of F. W. Lanchester to aerodynamics and operational research, he commenced by discussing the theory of lift, attributed to Newton, that showed lift to depend upon the square of the incidence: it was his view that Newton had expected this to be true in air since he had made calculations relevant to real bodies. This theory led to a pessimistic view of the possibility of flight, since the low incidence demanded for high lift/drag ratios would correspond to minute wing loadings. The Lanchester theory establishing circulation was refused publication by both the Royal Society and the Physical Society, and eventually had more rapid acceptance in Gottingen, where von Kármán was a student, than in this country.

Lanchester subsequently investigated the stability of aeroplanes, or "aerodromes," and proceeded to study their use in war, performing some of the fundamental work in theory of games. Dr. von Kármán entertained the large audience by discussing the origins of "phugoid" and "cathedral" (anhedral), and by recalling that when he expressed dismay at the speed of Lanchester's driving, the answer was: "I thought your name was Car-man!'

DOUNREAY ATOMIC ENERGY ESTABLISHMENT

Fig. 1—On the left is the main ventilating shaft of the chemical group. In the centre is the highly active liquor evaporation plant. Further to the right is the fast reactor and on the extreme right the circulating water pump house

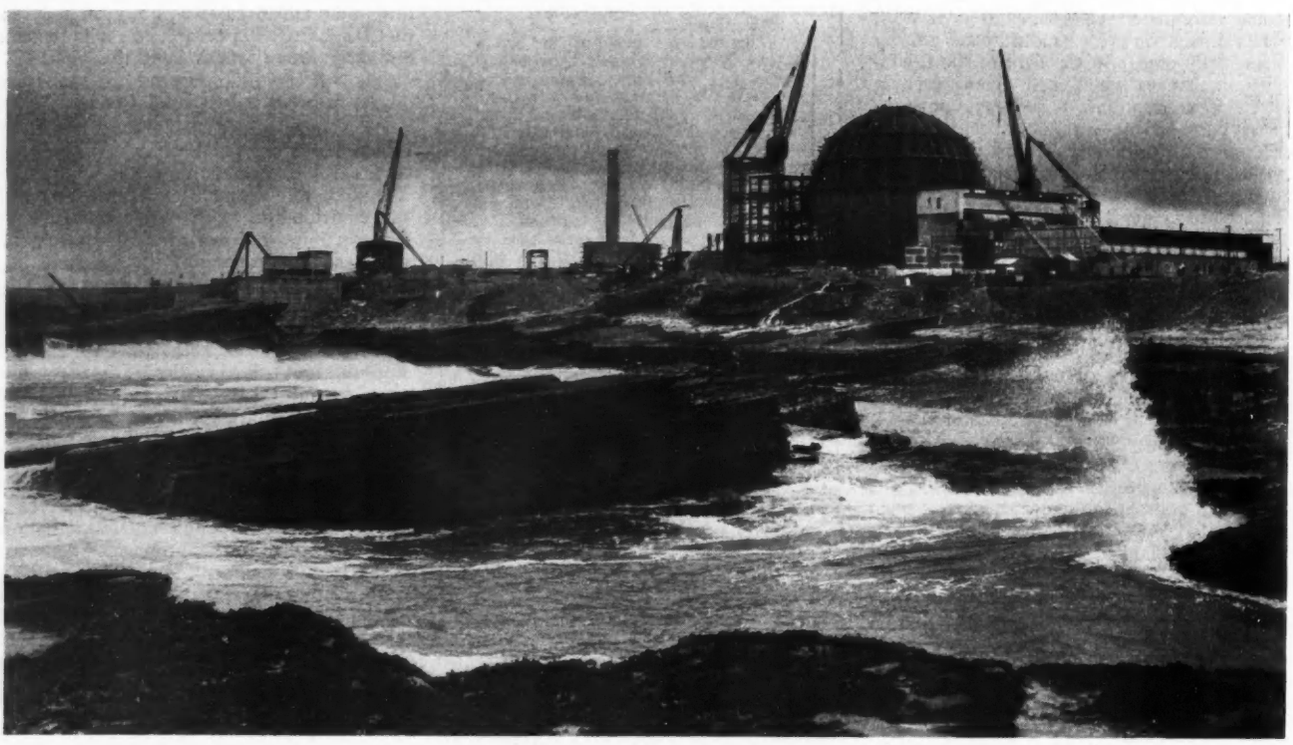
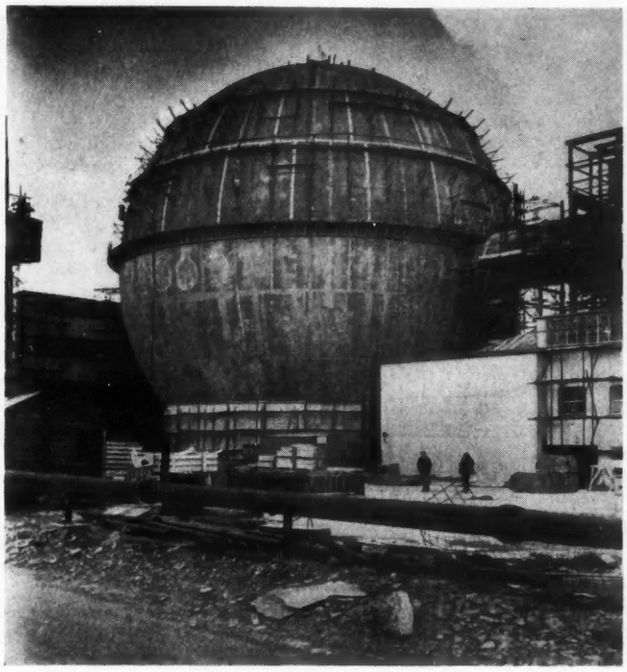


Fig. 2—The circulating water pump house on the left is equipped with four diesel-engine-driven pumps to handle 2,000,000 gallons of cooling water per hour. The cylindrical shell to the right of the pump house contains "Pluto," a heavy water reactor. The fast reactor, with its heat exchanger building, is on the right

Dounreay Atomic Energy Establishment

No. I

Dounreay is an experimental and research establishment of the Industrial Group of the United Kingdom Atomic Energy Authority. Its function is to yield information about the operation of large-scale experimental reactors. This information should provide the engineering basis for building and operating the advanced reactors that are likely to constitute the second and third stages of Britain's nuclear power programme. Some of the installations at Dounreay are described here. The main one is the fast reactor which is due to become critical in April, 1958.



UNLIKE the other establishments of the Industrial Group of the United Kingdom Atomic Energy Authority, Dounreay is not primarily a production plant. As Sir Christopher Hinton explained during the recent press visit to Dounreay the installations there are designed to provide information by the operation of large-scale experimental nuclear reactors. This information should enable Great Britain's nuclear power programme to advance from the first stage, based on gas-cooled graphite moderated reactors, to the later stages involving liquid-cooled thermal reactors, and "breeder" reactors with a "positive gain factor" which will allow better utilisation of the nuclear fuel.

Before advanced reactors such as these can be built and operated on an industrial scale as part of the British nuclear power programme a great deal of experimental information will be required on the behaviour of fuel elements, cooling systems and control techniques. Operational experience will also be needed to establish commissioning procedure.

To obtain this kind of engineering experience two reactors are at present being built—one is a fast breeder reactor and the other is a materials testing reactor (known as DMTR), which is moderated and cooled by heavy water and is similar to the Pluto reactor at Harwell. Installations are also being set up at Dounreay for the manufacture of fuel elements for the fast reactor and DMTR and for the processing of these elements after irradiation. The ancillary services which are being provided on the Dounreay site include laboratories for analytical and experimental work, mechanical engineering and instrument workshops and a health physics centre.

Another project recently undertaken at Dounreay is the land-based prototype for the submarine reactor which is to be built by the Admiralty. The U.K. Atomic Energy Authority is responsible for constructing the foundations and buildings and for providing the ancillary services.

The Dounreay establishment is sited on a disused naval airfield a few miles from Thurso, on the Caithness coast. The site is generally flat, sloping slightly northwards towards the coast. Use was made of existing airfield runways for access to the site, and for hard standing for concrete batching plant and other contractors' equipment as well as stores. The main entrance to the establishment and the fast reactor were sited on the axis of one of the main runways. On the two sides of this axis administration buildings and chemical laboratories were arranged informally to constitute an open quadrangle, loosely framing the view dominated by the sphere containing the fast reactor. To harmonise with the undulating character of the countryside and to reduce the effects of high winds most of the buildings are of one or two stories.

The Fast Reactor

The fast reactor at Dounreay (Figs. 1 to 3) is designed to operate as an experimental "breeder" reactor in which enriched uranium 235 or plutonium is used as fuel in the core and the relatively plentiful uranium 238 or thorium as fertile material in the blanket; more fissile material is formed in the breeding blanket than will be "burned" in the reactor core. Heat is produced by the fission of uranium 235 and uranium 238 in the reactor core. Because the fast neutron chain reaction cannot be sustained in natural uranium 238 the fast reactor core contains a higher proportion of uranium 235. The reactor core, in which 60MW of heat can be generated, is 21in in diameter and 21in high, and consists of uranium rods, sheathed in niobium containers, arranged vertically in a closely packed array. Around the reactor core is the breeder blanket, which consists of about 2000 rods of natural uranium arranged vertically, each rod being 8ft long and 1¼in in diameter.

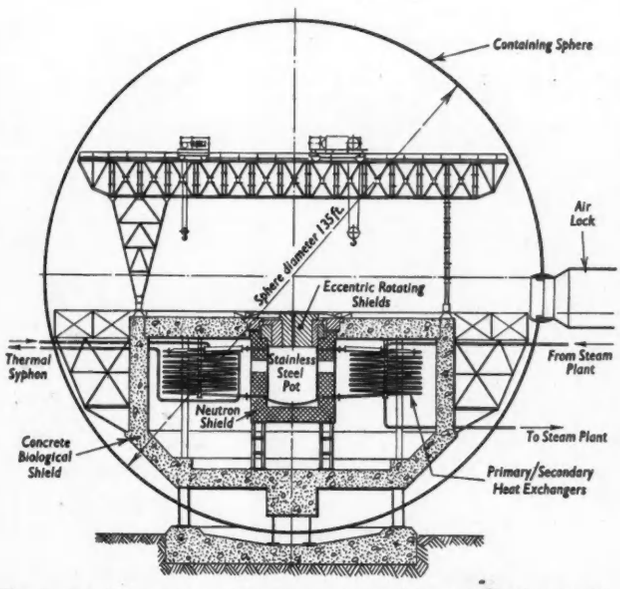


Fig. 3—The fast reactor at Dounreay is contained in a 135ft diameter fabricated steel sphere which is designed to contain any fission products or fire that may result from a reactor fault. Access to the reactor is obtained through an air lock chamber which can be seen on the right

Both the core and breeder are contained in a stainless steel reactor vessel, 10ft 6in in diameter and 20ft in length. Cooling is effected by liquid sodium-potassium, which is pumped into the top of the reactor vessel and then flows down over the core and breeder, removing the heat generated by fission and transferring it to a series of concentric-tube heat exchangers inside the reactor vault. A reinforced concrete structure known as the reactor vault (Fig. 4, page 748) encloses and supports the reactor vessel and all the heat exchangers and coolant pipework associated with the primary cooling of the reactor core and breeder. The vault itself is contained in a hollow, fabricated steel sphere 135ft in diameter.

Inside the concrete vault heat is transferred from the primary liquid metal coolant to liquid metal in a secondary coolant circuit in the concentric tube heat exchangers (Fig. 6). The secondary coolant is then pumped in stainless steel pipes to the heat

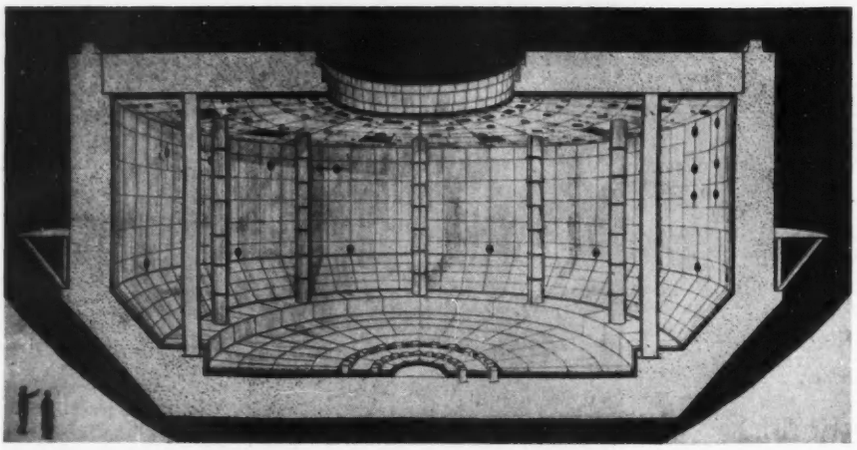


Fig. 4—Section through reinforced concrete vault of fast reactor, showing cleading in vault and some of the many cut-outs which had to be provided

exchanger house, which adjoins the reactor sphere. In the heat exchanger house the heat in the secondary liquid metal coolant is transferred to water in a set of copper-bonded heat exchangers of special design, which is described below. The steam produced will eventually be used to drive a 15MW turbo-alternator installed in the turbine hall behind the heat exchanger house. The scheme of the heat transfer circuits is outlined in Figs. 5 and 7. Control of the reactor is effected from the control room at the end of the administration building. Behind the administration building is the element storage building in which new fuel elements are stored and irradiated elements are handled before going into the cooling pond.

A link building next to the heat exchanger house contains electrical equipment and switchgear primarily for instrument supplies. Alongside there is a diesel generator house which contains two groups of diesel generator sets ; one group supplies electrical power to all pumps and equipment in the main reactor cooling circuits, while the second group gives standby electricity supplies for auxiliary reactor plant in the event of failure of the grid supply.

On the sea coast about 100 yards from the reactor is the sea water pump house ; in it are four diesel driven pumps which supply sea water for cooling the condenser of the 15MW turbine and for cooling auxiliary plant in the heat exchanger house.

Sphere and Concrete Vault Shielding.—The reactor sphere is 135ft in diameter and is fabricated from sections of mild steel plate varying in thickness between 1in and 1⅞in. Generally the thicker plates (1¾in and 1⅞in in the lower half of the sphere) were made from "Coltuf 28" steel and the thinner plates (in the upper part of the sphere) to Lloyd's P403 specification. In particularly highly-stressed areas around the base of the sphere " Coltuf 32 " steel was used. The steel plate used was cold pressed hydraulically into shape prior to being welded ; all the welds were radiographically inspected. The sphere has a surface area of about 1½ acres and weighs over 1500 tons ; the difference in pressure between top and bottom is 12 lb per square foot.

The sphere has two functions : first to localise the spread of fission products that might be accidentally released within the sphere ; secondly to withstand any pressure variations that might occur as a result of a liquid metal fire within the sphere.* Such an occurrence should not increase the pressure inside the sphere by more than 18 lb per square inch or reduce it more than 3 lb per square inch.

Access to the sphere is through an air lock 40ft long and 16ft in diameter, with airtight doors at each end ; the air lock permits entry to the sphere at the level of the mid-point of the sphere from the adjacent element storage building.

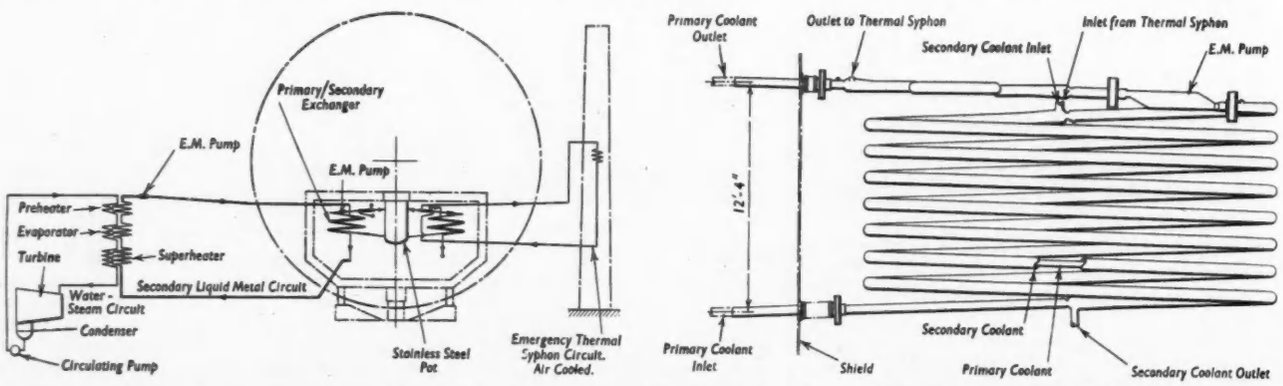
To prevent any radiation hazard inside the reactor sphere, the reactor and primary coolant circuits are contained in a concrete biological shield known as the reactor vault. A sectional view giving an impression of the vault is given in Fig. 4. The structure is in the form of a bowl 90ft in diameter and 45ft high with 5ft thick walls. The roof slab has a central hole immediately above the reactor vessel. Special attention was given to quality control of the concrete batching to ensure uniform density of concrete not less than 145 lb per cubic foot.

All internal surfaces of the vault are lined with metal-clad insulation panels. These panels form part of the cooling system for all internal vault surfaces, protecting the concrete shielding and roof columns from the effects of the high operating temperature inside the vault. All the 1200 panels required were constructed from mild steel sheets and plates packed with mineral wool to accommodate over 500 perforations formed to suit the labyrinth of pipes, plant and equipment housed in the vault. With this large number of fixed location points a very high degree of accuracy in construction and erection was required and to ensure this, sections of panels were preassembled at the Bury works of the manufacturer, Henry Hargreaves and Sons, Ltd. The insulation was fitted, clamped and sealed in position on a system of mild steel support channels and stools arranged so as to allow free and even air flow over all concrete and roof support column surfaces with a two-pass system serving the roof. The cooling air is introduced on a closed circuit at floor level in the vault and is forced over wall and roof surfaces before extraction at roof level for cooling and recirculation.

Further shielding is provided around the reactor vessel to prevent the secondary liquid metal coolant and the pipework within the reactor vault from becoming radioactive. This shielding consists of a 4ft layer of borated graphite in which an equatorial region of pure graphite permits fission rate measurements to be taken.

The design, fabrication and erection of the sphere was carried out by The Motherwell Bridge and Engineering Company, Ltd. The sphere is supported on and anchored to a fabricated steel skirt, whereas the " Horton-spheres " made by the company (for the oil industry, for example) are supported by columns.

Reactor Core and Blanket.—The fast



Figs. 5 and 6—(Left) Diagrammatic arrangement of liquid-metal and steam circuits of Dounreay fast reactor. (Right) Outline of a primary/secondary heat exchanger loop

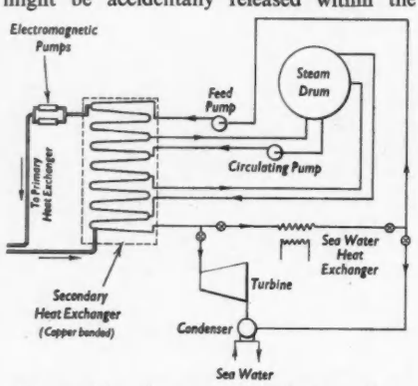
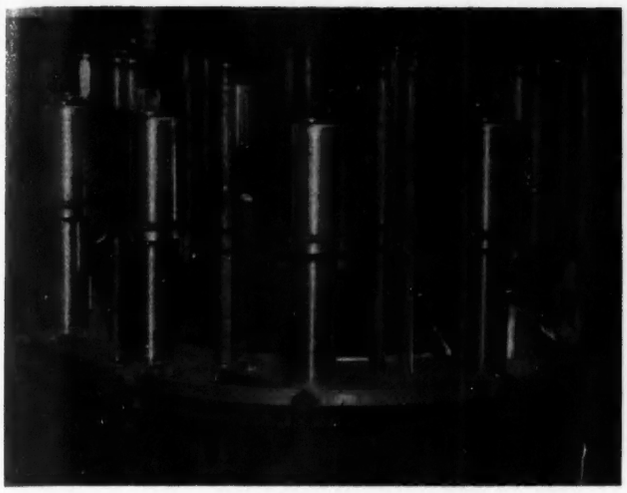
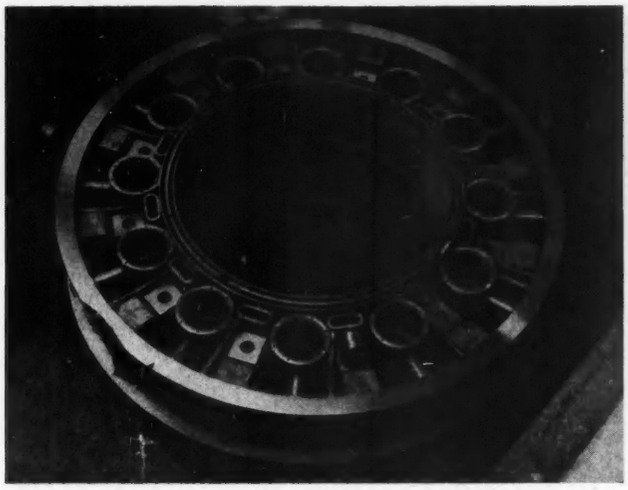


Fig. 7—Schematic arrangement of steam plant

* "Dounreay Fast Reactor Project," J. W. Kendall and T. M. Fry. International Conference on Peaceful Uses of Atomic Energy, Geneva, 1955. THE ENGINEER, September 2, 1955, page 330.



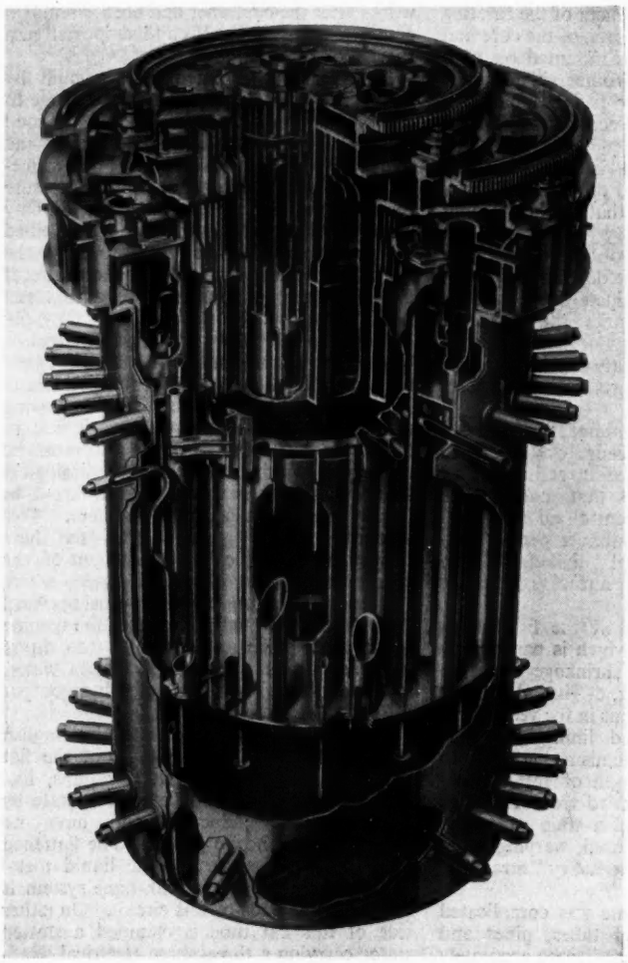


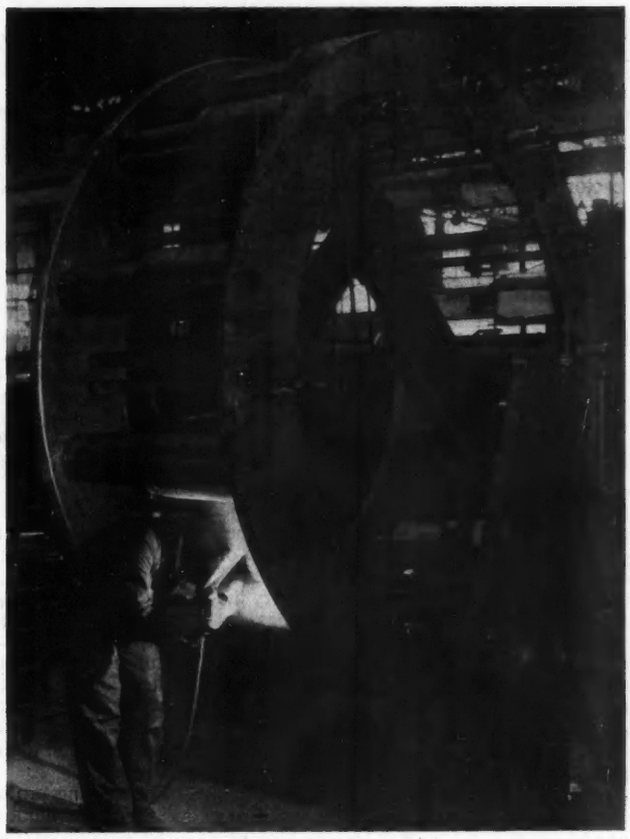
Figs. 8 and 9—(Left) Welding control rod tubes and pipes to a ring which forms part of the pressure vessel. To allow for butt welding, the ring was made from thick plate machined away to leave the bosses for weld preparation. (Right) Upper part of vessel during manufacture at maker's works. One of the rollers on which the top shields will rotate is in position. The central three-walled cylinder mates with a double skirt in the top shield to form a liquid seal

reactor core consists of fissile material, in which the majority of the fission processes occur, surrounded by a " blanket " of fertile material which reflects escaping neutrons into the core, and in which fresh fissile material is generated. Heat generation occurs mainly in the central portion, the core proper, which has the shape of a hexagonal prism 21in high and 21in across the flats, made up of several hundred fuel elements of annular cross-section. Each fuel element contains, at either end, a length of natural uranium, to form the top and bottom of the blanket or breeder material. The blanket is completed by surrounding this central portion of the core with approximately 2000 natural uranium rods 8ft long and 1¼in in diameter.

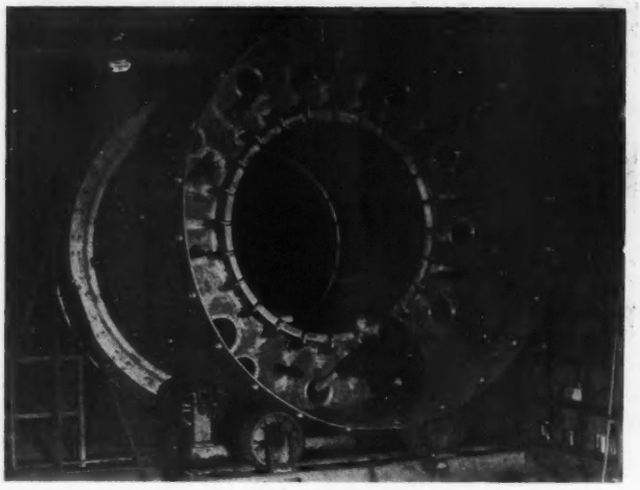
When the reactor is operating at its designed power output, the heat generated (60MW) is removed by the liquid metal heat transfer medium, which also cools the blanket. This liquid metal flows down between the fuel elements and blanket elements, and down the inner tubes of the fuel elements. Each element is positioned in, and supported by, the stainless steel bottom plate of the reactor, whilst adequate space for the flow of the liquid metal coolant between the elements is maintained by the fins on each outer can.

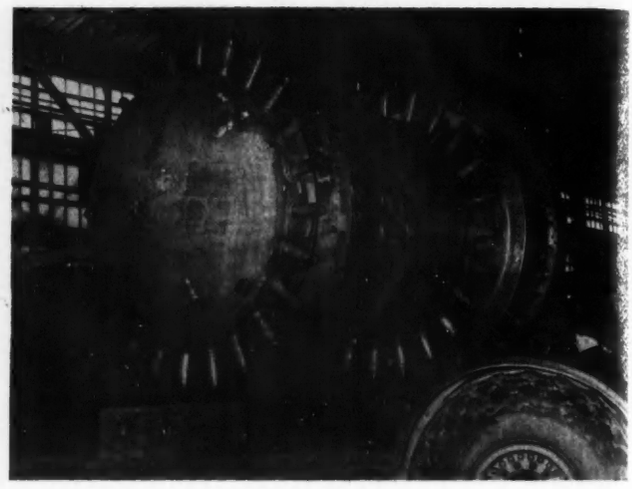
To contain the fissile material and fission products and to give dimensional stability to the core and blanket lattice, each fuel element is canned in niobium and each blanket element is canned in stainless steel. Niobium has a high melting point and a good resistance to hot uranium and sodium ; stainless steel is used for canning the blanket elements, because the conditions are less severe, but it





Figs. 10 and 11—(Left) Stainless steel container for Dounreay fast breeder reactor. The outer shell is double-walled with a dished base. The top of the container consists of rotating plugs which are graphite filled and arranged eccentrically one within another, so that a limited opening in the inner shield can scan the whole core and breeder blanket contained in the inner " skirt." (Right) Assembly of control rod tubes and pipes in manipulator for welding to support ring





Figs. 12 and 13—(Left) Stainless steel vessel during fabrication, before fitting of domed bottom or outer jacket. The ends of the tubes for control rod mechanisms and instruments can be seen around the inner skirt which will contain the reactor core and breeder blanket. (Right) Completed pressure vessel for fast breeder reactor being stowed for transport to Dounreay by road

is worth noting that these "less severe" conditions are, in the case of the blanket elements, nearer the reactor core, more severe than those experienced by thermal reactor fuel elements.

The neutron flux and, therefore, the heat generated in the core, is controlled by moving groups of fuel elements into and out of the core, the former movement giving increased reactivity. The fuel elements used for this purpose are identical to those in the normal reactor charge.

It should be appreciated that this fast reactor is an experimental tool and, therefore, it has been designed so that minor and major components can be easily replaced to allow different component designs to be tested. The whole of the core and blanket assembly within the double-walled reactor vessel can be removed and replaced by alternative assemblies, if required.

Stainless Steel Reactor Vessel.—The stainless steel vessel contains the core and the breeder blanket, the control rod operating mechanisms, the instruments that record reactor activity and the liquid metal which acts as coolant. This vessel, which is 20ft in height and 14ft in overall diameter, and weighs nearly 45 tons complete with top shields, is believed to be one of the most complicated stainless steel containers in existence. It was made by John Thompson, Ltd., Wolverhampton.

As illustrated in Figs. 8 to 13, the container consists of a double-walled cylindrical outer shell, with domed bottom and flat top, with a smaller inner cylindrical "skirt" reaching to about two-thirds of the depth of the outer vessel. This inner "skirt" will contain the core, blanket and control rods. Between the periphery of the "skirt" and that of the outer vessel are a series of tubes and narrower pipes running from the top of the vessel to various levels below the base of the "skirt." These tubes and pipes carry the operating mechanisms and connections for the control rods and instruments which will enter the core area from the bottom of the "skirt." At the tops of the pipes, instrument boxes are welded in position and pipes carry connections from these boxes out through the wall of the vessel. Similarly, pipes from the control rod mechanism tubes carry connections through the upper wall of the vessel.

The double walls of the outer vessel are of $\frac{1}{4}$in and $\frac{1}{2}$in plate with a $\frac{1}{8}$in gap between, forming a jacket around the vessel which will be gas-filled in connection with the leak detection system. At two levels around the outer vessel there are stubs to which the ingoing and outcoming liquid metal pipework will be welded; the inlet is at the upper level. Inside the vessel the flow divides. A proportion passes through the blanket area and does not mix with the main body of the coolant, being led to four of the outlet stubs at the lower level.

The top of the vessel is a complex arrangement of rotating shields or plugs, graphite-filled and disposed eccentrically one within another so that a limited opening in the inner shield can, by movement of the rotating elements, scan the whole area of the core and breeder blanket. Rollers mounted on pads on the vessel carry the outer shield; this shield in turn has roller pads which carry the inner shield mounted eccentrically within it.

While the reactor is in operation the rotating shields are raised off their rollers by a jacking mechanism so that the heavy rings which form their periphery make a firm seat with machined surfaces on the member on which they are mounted. In addition, liquid seals are maintained between each rotating part during charge and discharge operations, by double cylindrical "skirts" on each shield, which mate with and rotate within complementary parts on the members which carry them.

Fabrication of the container was carried out to tolerances much more exacting than those normally demanded in stainless steel vessels; typical limits that had to be observed were 0·1 per cent circularity, 0·03 per cent alignment and almost perfect concentricity where several diameters were involved, as in the mating surfaces of rotating shields.

On the diameter of 14ft the fabrication was executed to $^{1}/_{32}$in, which is particularly exacting because of shrinkage of the diameter, due to welding, of $\frac{1}{4}$in. Apertures for control rod mechanisms in the vessel were machined to 0·003in and lining-up of the tubes carrying these mechanisms had to be to a limit of $^{1}/_{32}$in in a length of 15ft. Components of the vessel varied from 12 gauge to $4\frac{1}{2}$in in thickness and a wide variety of welding methods were used, varying from miniature argon torches to heavy "straight" electrodes.

The welding programme was complicated by the large number of tubes, pipes and instrument boxes which had to be accurately positioned when built into the vessel. A sequence of assembly had to be determined to provide accessibility for welding and to prevent distortion resulting from welding, machining and stress relieving. Accessibility alone determined the procedure in the fabrication of some of the components and full-scale "mock ups" had to be made and special tools devised as a prelude to the establishment of a sequence of operations.

To ensure that the completed container should be leakproof 100 per cent examination of every welded joint was carried out by X-ray or gamma-ray. Final pressure and mechanical testing was done at the maker's works after the container had been assembled complete with top shields and supported in a speeially built mounting.

A special steel framework was built by John Thompson, Ltd., to prevent damage to the pressure vessel on its journey by road from Wolverhampton to Middlesbrough and thence by ship to Wick. To test this framework and to provide a test for the pressure vessel mountings at Dounreay a dummy vessel was built at the works; it was filled with concrete and was made to have the same flange dimensions, weight and centre of gravity as the stainless steel pressure vessel itself.

Fast Reactor Heat Exchange Systems.—Initially, the liquid metal to be used for heat removal is an alloy of sodium and potassium. Because it becomes radioactive passing through the reactor, and because it is contaminated by fission products, it must be contained within the concrete biological shield. Its heat is therefore transferred to liquid metal in a secondary system. This secondary liquid metal carries the heat through the biological shield and out of the sphere to the heat exchanger house, where the heat is given up in a steam-raising plant. Any steam generated in excess of the turbine requirement spills automatically into dump condensers which are cooled by sea water, and can absorb the full reactor heat output if the turbine is not running.

The liquid metal is circulated by English Electric electromagnetic pumps, of the flat linear induction form. These pumps, like the three-phase induction motor, operate by electromagnetic induction and have no moving parts, and no glands. The flattened pump tube forms part of the liquid metal circuit, and to secure a leak-tight system is welded to the ends of this circuit. On either side of this flat tube is clamped a slotted stator carrying a three-phase electrical winding, with class-H insulation of mica-glass-silicone. The complete pump operates in a steel tank provided with a vertical access

column. The stators can be lowered down this column and clamped on to the pump tube by remote means. Stators can thus be replaced without disturbing the hydraulic circuit.

Twenty-four electromagnetic pumps are used in the active primary circuits. Another twenty-four electromagnetic pumps are used in the non-active secondary circuits. The pump tubes and stators on the secondary circuits are interchangeable with those on the primary circuits.

The windings can be removed without opening the liquid metal system ; in the primary circuits this operation can be done by remote control through the biological shield.

These electromagnetic liquid pumps are described more fully in an article on page 752.

Complete failure of the heat removal plant would very quickly result in overheating of the reactor, and to prevent such a failure the heat removal is shared among twelve independent and identical units. A unit comprises two primary liquid metal circuits, one secondary liquid metal circuit, a steam-raising plant and a dump condenser. Each unit has an independent electrical supply from its own diesel alternator, so that the risk of a large-scale electrical failure is remote.

If, in spite of the above precautions, a widespread failure of heat exchange plant occurred, it would not be sufficient to shut down the reactor, because some heat would be generated by fission product activity after shut-down. A thermal siphon system of heat removal is provided (Fig. 6), which uses no electrical power, but relies solely on convection effects to dissipate heat to the atmosphere. Convection causes a circulation in the primary liquid metal system from which heat is transferred to liquid metal in the thermal siphon system. This liquid metal is also circulated by convection and transfers its heat to the atmosphere through heat exchangers in the stack. The system also dissipates a certain amount of heat during normal running.

The heat exchangers which transfer heat from the primary coolant circuits to the secondary circuits are all of tube and annulus design. Since the liquid metal reacts violently with water, the steam-raising heat exchanger has been designed to prevent leaks from one side to the other. Stainless steel tubes carrying the liquid metal and the water are bonded in a common copper matrix which ensures that a leak of either fluid escapes to atmosphere. Apart from the heat exchangers, the twelve steam-raising plants are similar in design to conventional forced circulation boiler systems.

Liquid-Metal Circuits and Heat Exchangers.—The primary heat exchangers are arranged in twenty-four banks surrounding the reactor vessel and contained within the concrete biological shield or "vault." The exchangers consist of inner and outer tubing spaced concentrically by spiders (Fig. 14). The inner tubing forms the primary circuit connected to the vessel. The outer tubing forms the secondary circuit which passes out of the "vault" to the secondary heat exchangers. Each primary circuit is provided with an independent electromagnetic pump and cold-trap purifier and two primary circuits are paired to serve twelve secondary circuits. Sections of the primary circuit not enclosed by the secondary circuit, that is, sections between the heat exchangers and the reactor vessel, are enclosed by tubes which form a gas-filled jacket monitored by the leak-detection apparatus. For maximum leak tightness, techniques were developed to enable the complete system to be built as butt-welded units with argon-arc slag-free seal runs. There are no valves in the system.

Quality control included "Introscope" inspection after hot drawing and after cold drawing to size, hydraulic testing and final inspection under water while air-filled to a pressure of 100 lb per square inch.

At the John Thompson works the process begins with cold bending of the tubes on a mandrel machine, using a special lubricant and dies to avoid steel pick-up during the operation. The tubes are then degreased and the bends subjected to heat-treatment to remove all bending stresses. Heat-treatment is carried to a temperature of approximately 1050 deg. Fah., after which the tubes are pickled in nitric and hydrofluoric acid to remove all scale.

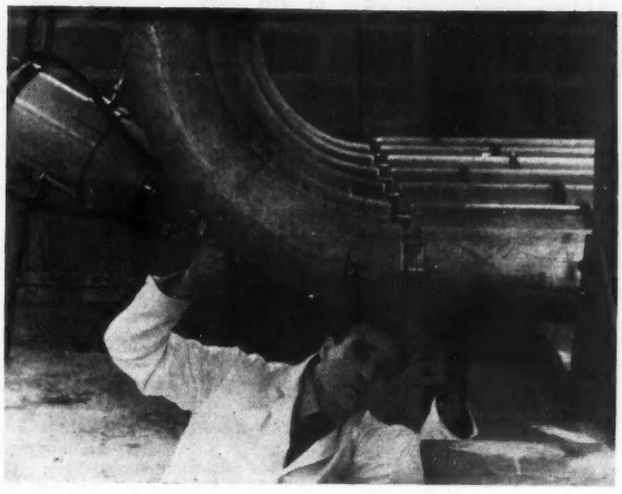


Fig. 15—X-ray examination of welded joints in inner and outer stainless steel pipework for primary liquid-metal heat exchange circuits for Dounreay fast reactor. During assembly the outer pipework can be parted sufficiently at the joints to permit X-ray examination of joints on the inner pipework

To allow of radiographic examination (Fig. 15), all joints are butt welded (Fig. 14) wherever possible. Tubes of thickness 14 gauge and above are machined on the ends to give the correct welding profile ($\frac{1}{16}$in maximum root face and $\frac{1}{16}$in lip). The necessity for butt welding requires that all branches and drain pockets be made by extruding a nipple (Fig. 16) on to a pipe and butt welding a short length of pipe on to the nipple. The internal bead in the welded liquid metal circuit is made as smooth as possible by control of the argon gas used in the argon-arc welding process. All separate elements are accurately fitted together with close butt joints. The inside of the tube is sealed close to the weld with soft rubber bungs, and the space between the bungs is filled with argon to reduce internal oxidisation and scaling to a minimum. The base run of the weld is made with an argon torch, fusing the walls of the tube without the use of filler wire. Subsequent runs are with filler wire of high-grade stainless steel. To ensure that the joints are leakproof completed units are X-ray examined by the double-wall technique. They are also tested for leaks by filling with nitrous oxide under pressure, with detection apparatus placed externally. Before leaving Wolverhampton the pipework assemblies were hydraulically tested, degreased by pumping a solution through the circuit, washed and given a light pickle, then dried and treated with heat, filtered air, removing all traces of water and dust. Rubber caps were fitted to the pipe ends for transport.

Fig. 16—A typical transitional piece of the Dounreay pipework. Extruded branch nipples are for junctions to leak detection circuits and secondary liquid-metal circuits

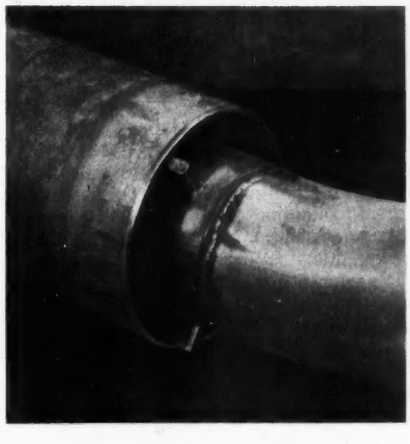


Fig. 14—Stainless steel pipework for liquid-metal heat exchange circuits. "Spiders" butt-welded in the inner circuit act as spacers between inner and outer pipework. The outer pipework shows the preparation for butt-welding

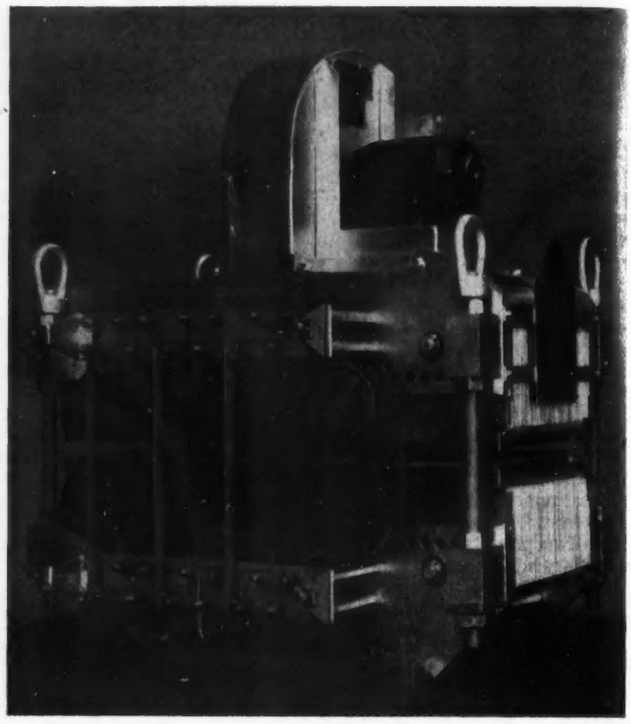
(To be continued)

PUMP FOR HIGHLY CORROSIVE CHEMICALS.—A bellows pump for use with highly corrosive chemicals has been developed by Crane Packing, Ltd., Slough, Bucks, in which all parts which come into contact with the fluid are made from "Fluon." The pump is stated to be able to handle all known chemicals and solvents except fluorine and the molten alkali metals, within the temperature range of −40 deg. to 80 deg. Cent. It is intended primarily for use in laboratories on short-term experiments, to provide highly corrosive liquids or gases at a predetermined pressure up to 30 lb per square inch, or as a metering pump providing an infinitely variable flow. The pump consists of a simple bellows made of "Fluon," which is blanked off at one end, and at the other end forms a valve chest incorporating two conical-seat gravity valves. Power is supplied by a reciprocating air motor with a fully adjustable stroke and sensitive throttle control, the pump bellows being directly coupled to an extension of the piston rod. The pump can be supplied in single-ended form, giving intermittent delivery, or as a double unit, to give almost continuous delivery.

Linear Induction Pumps for Liquid Metals

By A. S. FENEMORE, B.Sc.(Eng.), D.I.C., M.I.E.E.

Many different kinds of electromagnetic pump are feasible for use with liquid metals, and all rely on the interaction between high current in the liquid metal and a magnetic field to produce a pumping force without the intervention of any moving parts. Probably most development has been done on the linear induction pump, and this is the type to be discussed in the present article. Such pumps have been under development in the Nelson Research Laboratories of the English Electric Company, Ltd., Stafford, since 1948.



THE main application for linear induction pumps is in the atomic energy field. Liquid metals are efficient heat transfer agents, and for high temperature work have the great advantage, over water, of much higher boiling points, thus enabling high temperature systems to be used at low pressures. When extracting heat from nuclear reactors some form of pump is necessary to circulate the liquid metal, and an electromagnetic pump has great advantages over a mechanical pump in that no seals, and no moving parts, are required. So far the bulk of the electromagnetic pumps used, or planned, for use with nuclear reactors are of the induction type.

Apart from the atomic energy field, industry is showing some interest in electromagnetic pumps, e.g. for the supply of heat for chemical processing, and for the bulk movement of liquid metals. Another application which has been proposed is the use of liquid metal in steam turbine reheat.

Linear Induction Pump

The linear induction pump is analogous to the squirrel-cage induction motor. Essentially the pump consists of a linear stator, laminated and slotted, carrying a polyphase (usually three-phase) winding, which produces a linear travelling magnetic field. This field induces currents in an adjacent sheet of liquid metal (contained in a thin-walled metallic tube), and the reaction between these currents and the field gives a uniform thrust in one direction in the body of the liquid metal, urging the latter through the pump tube. The essential requirement from the fluid to be pumped is that it be electrically conductive.

In the flat form of pump the pump tube itself is flat, and it is convenient to use one wound stator on either side of the tube. This gives a construction in which the electromagnetic parts (that is, the two wound stators) can be removed without disturbing the hydraulic circuit. As liquid metal circuits are normally all-welded, this is a distinct advantage. This construction has other advantages also ; arranging one half of the winding on either side of the pump tube tends towards uniformity of field in the liquid metal and minimises the leakage flux in the slots.

The flat pump tube may have either :

(i) Thin, unsupported walls, with the reaction due to internal pressure taken by clamping the cores together, or

(ii) Thicker walls and internal webs, so giving a tube which is self-supporting under both pressure and vacuum conditions.

The webs would normally be pierced to minimise resistance of the paths of the currents induced in the liquid metal. This tube design gives some reduction in pump efficiency, but greatly increases robustness and reliability. Pumping effort and efficiency are both improved by copper side-bars along the two edges of the pump tube ; this copper has the same function as the end rings of the squirrel-cage rotor.

An alternative form of linear induction pump is the annular type. In this two thin-walled tubes are arranged to form an annulus filled with liquid metal. External packets of slotted laminations containing disc type coils provide the linear travelling field ; further unslotted laminations are provided inside the inner tube to give return paths for the magnetic flux. The currents induced form closed circles within the annulus of liquid metal, and side-bars are, therefore, unnecessary. As all the ampere-turns have to be provided on one side of the air gap, very deep slots are necessary, giving high leakage flux and low power factor. Two forms of the annular pump are possible :

(i) The " straight through " type. As the disc coils surround the annulus, a defective coil can be replaced only after the complete pump has been removed from the hydraulic circuit. This type appears to be more suited to the smaller designs.

(ii) The " reflex flow " type. In this type the liquid leaving the annulus is collected and turned back to flow through a tube inside the annulus and internal laminations. In this construction the liquid metal enters and leaves at the same end of the pump ; this makes it possible to remove the assembly of external laminations and coils without disturbing the hydraulic circuit.

A complete pump includes section changers (or diffusers) to change the liquid cross section from the configuration required by the pump tube to the circular cross section of the piping of the external circuit.

The theory of the linear induction pump was developed in 1952, and since then it has been possible to design a pump to meet a given specification.

400 G.P.M. Pumps

In 1952 a contract was received to design and build several pumps, each to deliver 400 g.p.m. of sodium at 250 deg. Cent. at a pumping pressure of 20 lb per square inch, the inlet pressure being up to 30 lb per square

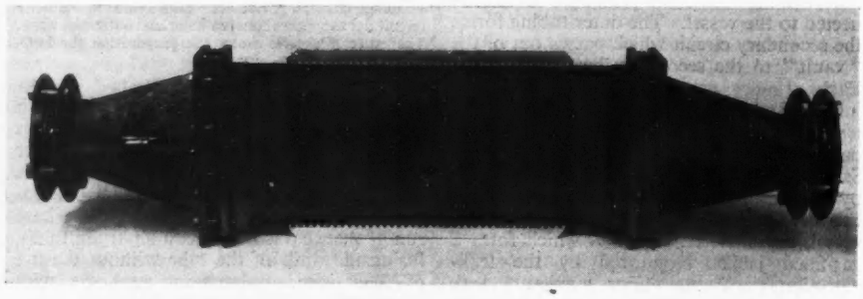


Fig. 1—400 g.p.m. electromagnetic pumps. The flat tube and section changers can be seen

inch. Initially the fluid pumped would be sodium-potassium (NaK). The pump tube walls were specified to be $\frac{1}{16}$in thick. The pump tube material was to be 18/8 stainless steel, and one additional tube was to be made in one of the Nimonics.

The main particulars of the design adopted are given below :

Internal dimensions of pump tube...	10in by 0·55in
Number of poles	3 fully wound, 2 half wound
Pole pitch	4·8in
Velocity in pump tube	28ft per second } Slip=
Velocity of travelling field	40ft per second } 0·30
Magnetic gap	0·80in

Since the liquid metal temperature is above the operating limit even for Class H insulation, heat insulation ($\frac{1}{16}$in of asbestos) is interposed between cores and tube, and the cores are cooled by blowing air from an integrally mounted fan through a large number of holes behind the slots in each core. The Class H insulation used is glass/mica/silicone.

Two of these pumps were set up in 4in N.B. pumping loops provided by the U.K. Atomic Energy Authority at Windscale Works, where, in conjunction with Nelson Research Laboratories, the pumps were tested for performance (see later section "Characteristics"), and were then put on long-term endurance tests. One of these pumps has now completed 16,000 hours of running, and the other 16,500 hours, without trouble. On one loop the temperature of the liquid metal was raised until the winding temperature reached 180 deg. Cent., and it was found that liquid metal at 340 deg. Cent. could be pumped continuously. These pumps are illustrated at the top of page 752 and in Figs. 1 and 2.

Efficiency

Induction pumps operate as induction motors of large air gap and high slip. The efficiency is relatively poor, partly due to the high slip. Since the "air gap" has to accommodate the two tube walls, and any heat insulation between cores and tube, as well as the moving sheet of liquid metal, the gap is large. It follows that a large excitation is necessary to get a reasonable flux density in the liquid metal, hence the stator I^2R tends to be high. Eddy currents in the liquid metal are essential to the operation of the pump, and the losses here are analogous to the rotor copper loss of a normal induction motor. (See heading "Liquid Metals.")

In addition, there are a number of losses which do not occur in the normal induction motor. There is an appreciable eddy current loss in the tube walls ; this loss will obviously be kept to a minimum by selecting, of those metals compatible with the liquid metal to be pumped, one of high resistivity. This loss can be limited also by keeping the walls thin ; the limit here is the degree of robustness required.

These pumps operate with a high liquid velocity in the pump tube, and there is therefore appreciable hydraulic loss in the tube. Since the complete pump includes the two section changers (in which any necessary change in liquid velocity between the external circuit and pump tube is made), hydraulic losses here have also to be debited against the pump efficiency. There are also "end effect" losses which do not occur in the normal induction motor. This effect is considered in more detail later.

As a result of all these effects the best efficiency which can be reached with a linear pump handling sodium is about 50 per cent. The efficiency falls progressively as the resistivity of the liquid pumped increases.

Characteristics

The characteristics of electromagnetic pumps are best represented by output head/flow curves, which for induction pumps are exactly analogous to the torque/speed curves of the induction motor. Fig. 3 shows the characteristics obtained ; the full-line curve is representative of a low resistivity fluid, such as sodium, and the chain-dotted curve of a higher resistivity fluid, such as sodium-potassium (NaK) alloy.

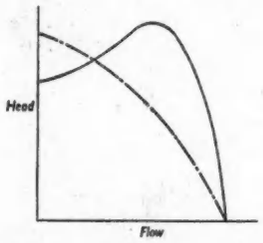


Fig. 3—Typical characteristics curves of electromagnetic pump

Pump characteristic curves may be considered in more detail. Fig. 4 shows a selection from the test results of one of the 400 g.p.m. pumps illustrated when pumping 70/30 NaK at 250 deg. Cent. Each of the head/flow curves shown was obtained under constant current conditions. Full-load current is 85A ; a portion of the curve at 91A (7 per cent overload) is also shown. The pump was tested in a 4in N.B. circuit which included a control valve so that the hydraulic resistance could be varied. With the control valve fully open (2in) the characteristic of the external circuit is given by the square law *OB*, and it is not possible for the pump to work below this curve, when used in this particular circuit.

The combined pump and circuit can operate anywhere within the area *OBC* ; the area may be regarded as being made up of a large number of hydraulic circuit characteristics, any one of which can be selected by

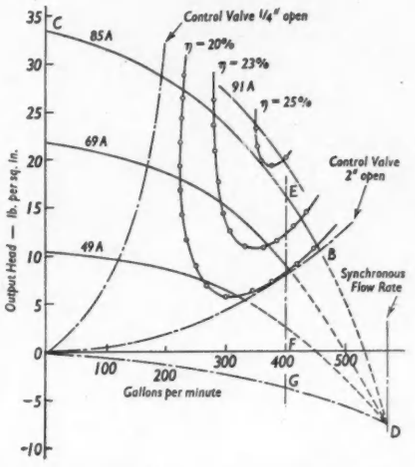


Fig. 4—400 g.p.m. pumps. Characteristic curves for 70/30 NaK at 250 deg. Cent.

appropriate setting of the control valve. The operating point on a particular characteristic is decided by the voltage applied to the pump, which in turn fixes the current taken. It is clear that variation of voltage gives a simple and satisfactory way of controlling the pump output.

The hydraulic losses within the pump can be calculated or, alternatively, may be known as the result of an air flow test, and can be represented by the square law *OD* below the flow axis. The pump characteristic curves must all tend towards point *D* on the synchronous flow line (i.e. the flow rate corresponding to a liquid velocity within the pump tube equal to the linear speed of the travelling magnetic field). The test curves may therefore be extended as shown by the dotted lines to point *D*.

When operating at 400 g.p.m. at 85A (i.e. point *E*) the head developed in the pump is *EG* ; of this *FG* is absorbed by the tube and section changers, leaving the useful head *EF* to drive the fluid round the external circuit. The useful pump output is :—

Pump horsepower=flow (g.p.m.)×output head (pounds per square inch)×0·0007.

If the electrical input is measured by wattmeters the pump efficiency is easily determined. Efficiency curves can be plotted normally, or points of constant efficiency may be plotted on the head/flow diagram. Three such efficiency curves are shown for efficiencies of 25, 23 and 20 per cent. Considering any one head/flow curve, the output is zero at no flow, rises to a maximum, and falls to zero again where the curve cuts the flow axis. Below is given a tabulation of a number of points on the 85A characteristic. This shows the pump has a good range of useful outputs at efficiencies ranging from about 80 to 100 per cent of the maximum.

Maximum output occurs at 320 g.p.m. and

G.p.m.	P.s.i.	Output, h.p.	Efficiency, per cent	*R*
230	27·5	4·4	20	5
280	25	4·9	23	3·7
320	22·5	5·0	24	2·9
360	19·5	4·9	25	2·24
400	16·5	4·6	24	1·7
425	14	4·2	23	1·36
455	11	3·5	20	1

R is proportional to output head divided by flow (i.e. Col. 2/Col. 1).

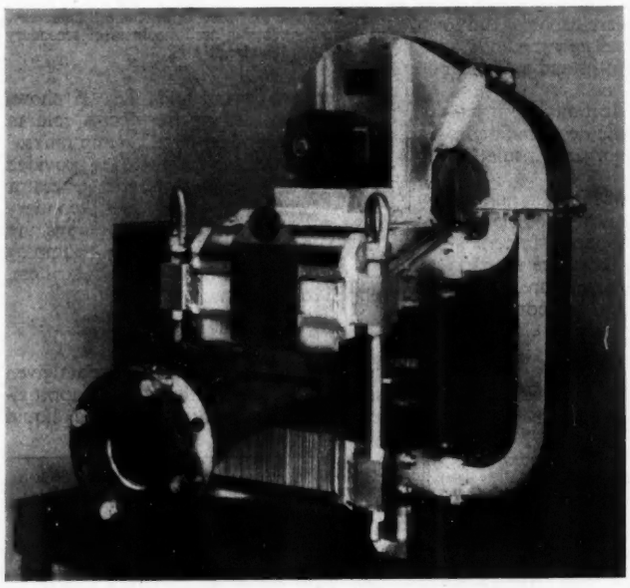


Fig. 2—Complete electromagnetic flat linear induction pump with rating of 400 g.p.m.

is 5 h.p. Mathematically, this is the point where the output curve is tangential to a hyperbola, the latter representing constant output. As mentioned earlier, these pumps were designed primarily for use with sodium ; with this liquid the output heads and efficiencies are appreciably higher.

Induction pumps can be designed so that at the required flow either the head or the output horsepower is a maximum, and generally so that the efficiency at the working point is at or near the maximum in the case of the liquid metals of lower resistivities.

Grading of Windings

Unlike the induction motor, in which the windings progress uniformly around the circular stator, linear electromagnetic devices have discontinuous windings. The discontinuity at each end affects the flux, sometimes throughout the device, and special measures have to be employed in the windings to obtain high outputs and minimise losses.

In the flat pump it is essential to avoid any appreciable pulsating field superimposed on the useful travelling field in the air gap. This can be achieved by having an odd number of fully-wound poles, together with one pole at each end which is half wound. It so happens that a two-layer winding lends itself admirably to this arrangement. If, for instance, enough coils for the full winding of four poles are spread over five poles, then the arrangement is one half-wound end pole plus three fully-wound poles plus one half-wound end pole. This winding does give pulsation in the core flux, but this is not important in the flat pump. (It may need a little more iron behind the teeth, and it may slightly increase the core loss, but this is quite a minor loss anyway.)

The problem is more difficult in annular pumps. As before, it is necessary to use a winding which does not give any appreciable pulsating field in the air gap. In these pumps the annulus of liquid metal and the two tubes of the annulus form short-circuited turns around the inner core. An additional condition is therefore that there must be no appreciable pulsation in the core flux, otherwise heavy currents will be induced which provide no pumping force but considerable extra loss. The conditions which have to be met by a winding for the annular pump are therefore more severe ; on the other hand, as disc coils are generally used there is more freedom in choosing the number of turns in any individual coil.

Inside the pump tube the liquid metal is travelling in a magnetic field, but beyond the pump tube the field is negligible. These rather sudden changes in the environment of the moving liquid, which occur at each end, produce transient currents in the liquid metal near each end of the pump tube, and a corresponding loss and reduction of output. Suitable grading of the winding reduces the amplitude of these transients, and calculations indicate that in e.m. pumps the transients decay quite quickly, so that the loss in performance due to transients can be kept quite small.

Electrical Insulation

With linear induction pumps the windings are necessarily near the pump tube containing the hot liquid metal. The temperature at which the windings can operate is decided by the type of insulation, and alternative methods can be used :—

(i) *Windings With Conventional Insulation.*—If the liquid metal temperature is above the temperature limit of the insulation, heat insulation is interposed between pump tube and wound cores and, if necessary, the cores are force cooled. The 400 g.p.m. pumps described earlier employ this method.

(ii) *Windings Operating Above the Temperature of the Liquid Metal.*—Where forced cooling is difficult to apply the windings may be designed to run hotter than the liquid metal. No heat insulation is used between cores and tube, and the heat from the winding in the slots is conducted partly to the liquid metal and partly to the core. From the latter heat is lost by radiation and convection to the enclosure. In some cases this means using inorganic insulations which can operate at high temperatures and an enclosed inert atmosphere to avoid oxidation of conductors, laminations and some other metal parts. The Dounreay pumps described later employ this alternative method.

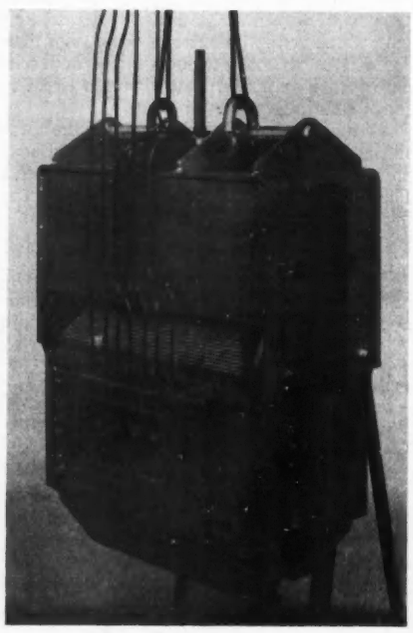


Fig. 5—Pump for fast breeder reactor at Dounreay. Stator clamping mechanism with both stators in place

Liquid metal temperatures are likely to increase as reactor design advances, and it has been clear for some time that it is necessary to determine the temperature limits of which existing insulations are capable, and to develop new materials, and new methods of application, capable of withstanding higher temperatures.

Usually in reactor applications the insulation has to withstand some degree of radiation ; from this aspect inorganic insulations are to be preferred.

One of the difficulties of high temperature windings is the temperature coefficient of resistivity of available conductor materials ; copper at 285 deg. Cent. has twice the resistivity of copper at room temperature. Hence, at constant current density, the copper loss goes up correspondingly.

Pumps for Dounreay

As is well-known, the Atomic Energy Authority is building an experimental fast reactor at Dounreay, North Scotland. The reactor will be contained within a steel sphere 135ft in diameter, and the heat produced, given as more than 60MW, will be extracted by sodium or sodium-potassium. The liquid metal will be pumped by linear induction pumps, and Nelson Research Laboratories were asked by the Authority to build two complete prototype pumps. These prototypes were tested for performance and endurance in the Research and Development Branch of the Authority's works at Capenhurst. While these tests were proceeding, the Authority placed with the English Electric Company, Ltd., the bulk order for the e.m. pumps required for the operation of the reactor.

As the sodium in the reactor core becomes radioactive it has to be kept within the biological shield, and a second sodium circuit, in which the sodium is not radioactive, is used to transfer the heat from the primary sodium to the steam boiler. Twenty-four e.m. pumps are used in the primary circuit, twenty for the reactor core, and four for the blanket. A further twenty-four e.m. pumps are used to circulate the sodium in the secondary circuits. In Fig. 5 we show the stator support gear, and Fig. 6 shows the stator gear entering the access column of one of the secondary circuit pump tanks.

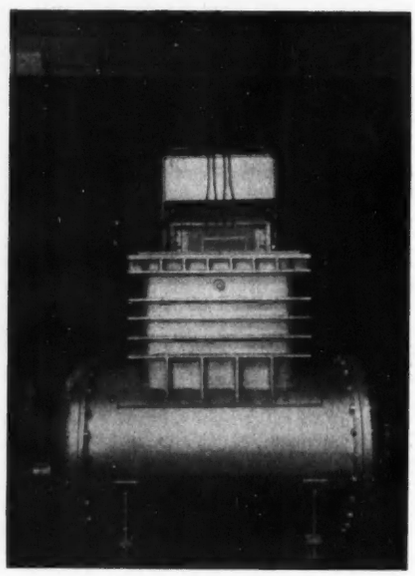


Fig. 6—Pump for fast breeder reactor at Dounreay. Stator assembly entering access column of secondary circuit tank

Electrical power for the pumps is provided by twelve diesel generator sets, each generator supplying two primary and two secondary pumps. By thus subdividing the pumps and generator sets, the reduction in total pumping power, due to the failure of a particular item, is reduced to a minimum.

Liquid Metals

The table below, compiled from data given in the *Liquid Metals Handbook*, gives approximate physical properties of some liquid

Metal	Melting point, deg. Cent.	Boiling point, deg. Cent.	Temperature, deg. Cent.	Resistivity (1)	Density (2)	Viscosity (3)
Solid copper...	(1083)	—	300	3·65	—	—
Liquid sodium	97·8	883	300	16·7	0·88	0·344
Liquid potassium	63·7	760	300	28·2	0·77	0·236
Liquid NaK (56/44)	19	825	300	46·5	0·84	0·287
Liquid lithium	179	1317	230	45·3	0·50	0·523
Liquid mercury	−38·9	357	300	127·5	12·9	0·90
Liquid bismuth	271	1477	300	128·9	10·0	1·66

(1) Microhms per centimetre cube. (2) Grammes per cubic centimetre. (3) Centipoises.

metals. The resistivity of solid copper is included as a reference.

Conclusions

Of the many advantages of using electromagnetic pumps, the linear induction pump has the following :—

(i) The operation of all e.m. pumps requires a high current in the liquid metal. In the linear pump this current is produced by induction. In other types this current is usually produced by auxiliary apparatus such as a transformer or homopolar generator.

(ii) Complete and stable control of the pump output is obtained by variation of the applied voltage. This control may be applied over a limited range, or over the whole range from zero to full output, and is conveniently provided by an induction regulator or regulating transformer.

(iii) Because the pump is supplied from a polyphase system, the output pressure is substantially constant throughout each time cycle. In single phase pumps the pressure developed varies from zero to maximum at twice the supply frequency.

Satisfactory designs for linear induction pumps for the liquid metals of lower resistivities, such as sodium, sodium-potassium and lithium, are available. Normally, little advantage is gained by departing from the standard frequency of 50 c/s.

For high resistivity metals such as mercury and bismuth, designs can be produced but the pumps tend to be rather bulky and low in efficiency. For these fluids the d.c. conduction pump is more efficient, but needs extremely high direct currents at only a few volts. This d.c. supply can be given by a homopolar generator, but it probably needs development ; alternatively, it can be given by a rectifier, but this equipment is likely to be bulky and expensive.

The linear induction pump is well-suited to the large flow, moderate pumping pressure, duties required for reactor applications.

Acknowledgments

The author is indebted to the Director of Research, Nelson Research Laboratories, for permission to publish, and to his colleagues in the laboratories for manufacturing the pumps and test loops, and assistance in testing the pumps.

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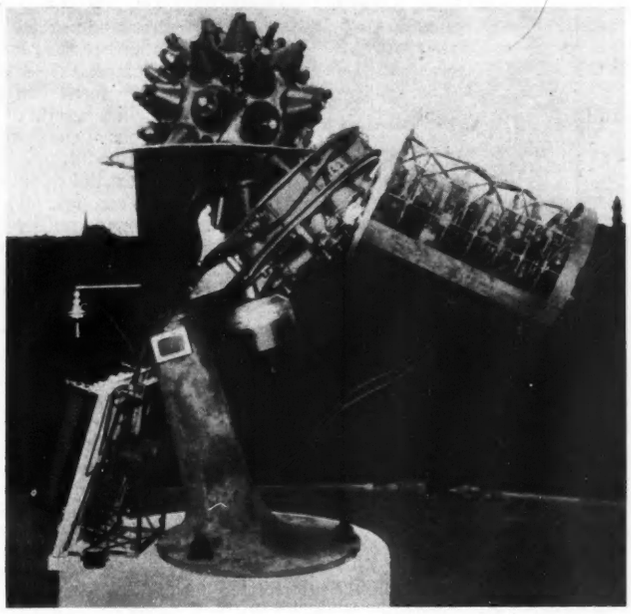
Projection Planetarium and Shell Construction

By PROFESSOR WALTHER BAUERSFELD*

No. I

Last Friday, May 10, a James Clayton Lecture before the Institution of Mechanical Engineers, was delivered by Professor Walther Bauersfeld. Between the wars, the Carl Zeiss company developed a very ingenious device for projecting images of the sun, planets and stars on to the interior surface of a dome, giving to those images their proper motions. Planetaria utilising this device were subsequently erected at several places in Germany, in America, in Italy and in Russia. A planetarium of the same kind is to be erected in London. Here Professor Bauersfeld tells the story of the development of the device. The construction of the necessary domical building led in turn to the development of shell construction and the lecturer tells the story of this development, too.



First Ideas About a Planetarium

ABOUT the end of the year 1913 the astronomer, Wolf, of the observatory at Heidelberg, had a discussion with Oskar von Miller, the creator of the Deutsches Museum at Munich—a collection of masterpieces of technical art of a similar character to the Science Museum in London—about the possibilities of instructive models for demonstrating the motions of the heavenly bodies. Mr. Wolf proposed to show the stars, with accelerated motions, to a small number of visitors in the midst of a dome of spherical curvature. For this purpose the dome should be constructed of thin iron plates welded together to a spherical form. These sheets should be provided with a large number of small holes of different sizes to represent the stars of the different magnitudes. The room surrounding this sphere should be brilliantly illuminated in order that the spectators on a small platform in the midst of the sphere would have the picture of the fixed stars on the black background of the inner surface of the sphere. It was proposed that the sphere should have a diameter of about 20ft. In order to show the daily motion of the fixed stars it would be necessary to give the hollow sphere a rotation on an inclined axis which would represent the polar axis of the earth. For this purpose the sphere should be mounted on a large ball-bearing about 16ft in diameter which would allow the provision of a staircase connecting the platform in the middle of the sphere with the floor of the outer room.

Certainly this construction would give a very satisfying picture of the fixed stars. But it had the disadvantage that visitors would have to wait for some time for their turn, when there were many. A great difficulty was, however, that the apparatus should also show the motions of the other heavenly bodies, sun, moon and planets. These should be represented by small illuminated discs at the ends of long bars, the motions of which were to be controlled by very complicated mechanical devices. But the bars and latter parts of these appliances had to have their place in the interior of the spherical dome and would disturb the visibility of the fixed stars.

Oskar von Miller proposed this difficulty to the Zeiss works at Jena, hoping that they would find a satisfying solution and also hoping that the Zeiss works would deliver the whole construction gratis and post paid. In that regard he was not disappointed. But the apparatus which was delivered in 1923 was very different from the proposed design.

The Munich Planetarium

The author, who had been a member of the board of management in the Zeiss works since 1908, attended a meeting at Jena between Oskar von Miller and the chief engineer of the astronomical department of the firm. On this occasion much was discussed about the difficulties of the construction, which appeared insurmountable. In this situation I asked the question : " Why do you want to make such complicated and

* Member of the Board of Management, Carl Zeiss, Oberkochen.

heavy machinery ? I think a much better way would be gained by optically projecting the pictures of the heavenly bodies on the interior surface of the sphere. In this case all the complicated mechanical machinery could be replaced by a fairly small arrangement of optical apparatus in the midst of the sphere." Immediately after I had spoken these words, my colleague in the board of management, Professor Straubel, who also had attended the meeting, exclaimed : " Then, of course, also the fixed stars should be projected from the central apparatus." This was the moment in which the Zeiss Planetarium was born. Oskar von Miller and all members of the meeting were very happy about this solution which, moreover, allowed enlargement of the dimensions of the spherical dome so that many more visitors could see the artificial sky simultaneously, and the astronomical department was charged with designing the apparatus in this form.

Some months passed and I was much occupied by many other projects and negotiations and heard nothing about the progress

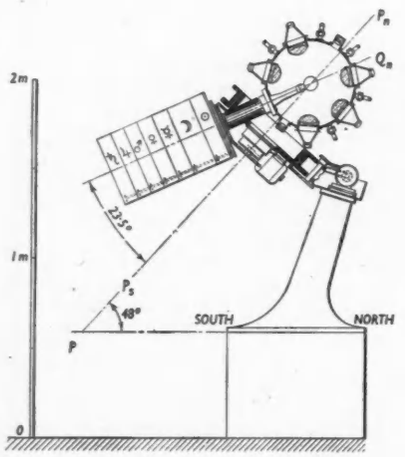


Fig. 1—Schematic drawing of the Munich instrument

of the planetarium construction. Until one day I found on my desk a letter addressed to Oskar von Miller from the astronomical department of the firm, which simply declared that after mature consideration it had been impossible to construct the suggested planetarium by optical projection. It would be necessary to return to the first plan, notwithstanding the difficulties and disadvantages which opposed this scheme. The writer of the letter regretted that it would be necessary to vary the partly constructed mural work of the room that was intended for the apparatus.

At this I was angry because I had not been informed about the recent difficulties which I could not consider as insurmountable. So I cancelled the letter and decided to attend personally to all details of designing the new apparatus. In the beginning I was not sure whether I should be able to master all the problems which would arise during the designing, therefore I engaged only one design engineer, with whom I could discuss all the details step by step. It took four years before the whole work was performed. During those years I was compelled to devote a considerable part of my time and thoughts to the problem. A great number of sketches and plenty of mathematical calculations proved necessary. But I was fortunate in that no real obstacles hindered me following the proposed method, and, at the end, the success was much greater than anybody could have imagined. The characteristic features of the apparatus are to be seen in the illustration on page 755 and in Fig. 1. An electric bulb of 500W sends light to thirty-one surrounding projection systems arranged on a hollow brass sphere of about 20in in diameter for the projection of the fixed stars and the Milky Way. This sphere is connected with a stage of cylindrical form containing, in seven separate shelves, mechanisms and projectors for sun, moon and the five planets which can be seen in the sky with the naked eye. Sphere and cylindrical stage rotate together slowly on their common axis, which represents the axis of the ecliptic. Further on, the whole system can be rotated on another axis which is inclined to the floor at 48 deg., corresponding with the latitude of Munich. This second rotation corresponds with the daily rotation of the earth, but is strongly accelerated. One turn of the apparatus can be performed in twelve or four minutes or one minute to allow the demonstrator to choose the velocity which he prefers for his lecture. The mechanics for the rotation is fixedly combined by gearwheels with the mechanics for sun, moon and planets and even with the axis of the ecliptic.

Annexed to this mechanism are provided three electro-motors which enable the motions of sun, moon and planets to be driven with much higher velocities so that the motions of one year are performed during four minutes, one minute or seven seconds. These motions permit demonstration of the extremely varying circuits of the planets. In a similar way a motor for a slow rotation on the ecliptic axis allows separate demonstration of the effect of the precession. The gearing is carefully calculated in order to show the correct positions of the planets for about 5000 years back and forth with an extreme deviation of only a few degrees.

Among all the problems connected with the construction of the planetarium only two proved especially difficult. The first was the image of the moon, with its variable phases, which had to be guided to conform exactly to the relative position of the sun. For the Munich apparatus this task was only approximately performed. Later on, we found a correct solution which gave a satisfying image of the moon with correct positions of the phases. In the universal planetaria which we built afterwards, this solution was used.

The second difficulty was the image of the Milky Way. First it seemed very simple, and so it was projected in a primitive manner for the Munich apparatus. But the effect was far from being satisfying. After many futile trials we succeeded in projecting a carefully designed picture of the Milky Way, whose details we gained from exact measurements of the brightness at a great number of points by the astronomer Pannekock, of the observatory at Copenhagen.

These examples concerning the details of the instrument may be sufficient here. An almost complete technical description of the universal planetarium has been published by the German-American writer, Mr. Henry Simon, in the *American Machinist*, 1929, in a series of five articles.

When we saw the artificial sky over us for the first time we were all surprised because we no longer had the feeling that our stars were projected at a distance of about 20ft, but they appeared as far as infinity, and the dark background of the heaven seemed to be coloured in dark blue although we had done nothing to create that. The former effect was very soon explained. If we regard with both eyes a star on the spherical dome it appears to us to be at practically the same distance as the neighbouring stars. Therefore, it is possible to estimate its

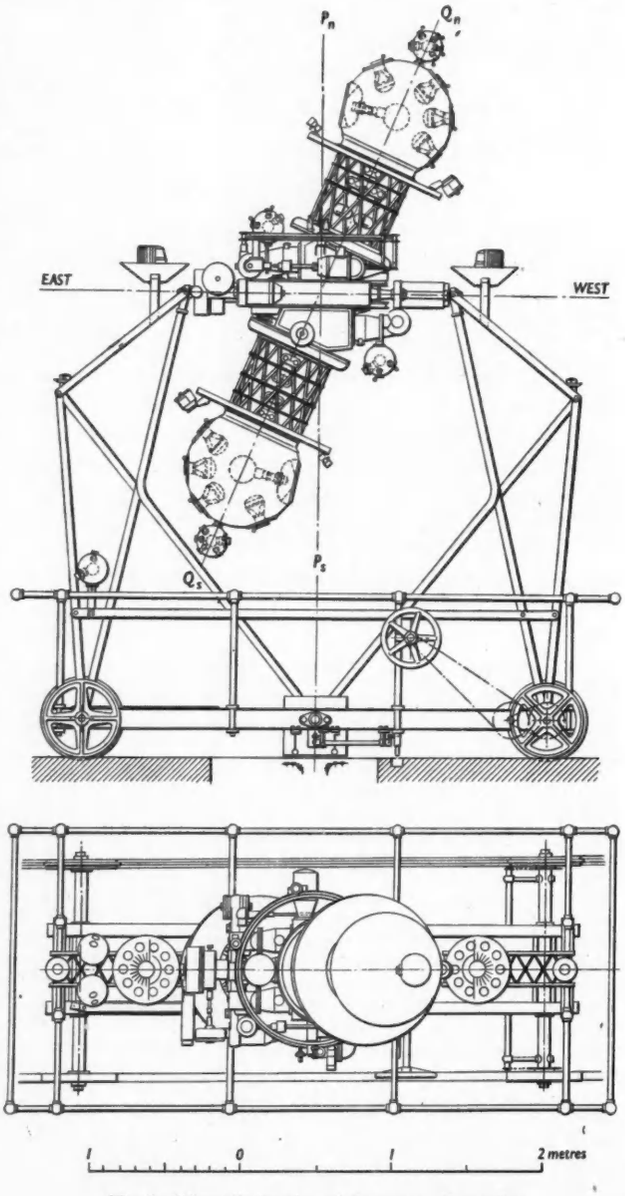


Fig. 2—Schematic drawing of the newest planetarium

distance, which ordinarily in our surrounding space is easy because we have a great number of objects at different distances before us, and these differences allow us to estimate distances because the two images which we perceive on the retina of both our eyes differ markedly in this case. For the second effect, the blue colour, we still lack a satisfying explanation.

The Universal Instrument

The aspect of our artificial sky proved so impressive, so fascinating, that anybody who heard about it was eager to see this new "wonder" of Jena, and we could not refrain from showing the planetarium to the public for some weeks before it was sent to its place of destination at Munich. It so happened that a great number of newspapers referred to this, and reporters came to gain a personal impression. But what was more important, representatives of some larger towns of Germany appeared and wanted to know if the firm of Carl Zeiss would sell them planetaria of this kind. They esteemed the instrument, on account of its educational value, in the first place for school classes, but they also thought of making money from it from the fees of visitors.

As we now saw the chance of selling a number of such instruments, it seemed advisable to design a second and improved model which allowed the sky to be shown not only for the latitude of Munich but for every place on the earth, including the poles and the equator. As we had gained the experience it was not difficult to construct a universal instrument which has since been delivered to more than thirty towns in many countries of the world and, last but not least, very soon such a planetarium will be erected in London.

This universal instrument (Fig. 2) differs from the Munich type chiefly in that the projecting apparatus is divided into two separate groups connected together by the ecliptic axis. Between them is a carrier which contains all driving motors and a large ball-bearing for the rotations of the whole complex of projectors on the pole axis conforming to the daily rotation of the earth. The angle between the pole axis and the ecliptic axis of 23½ deg. corresponds with the natural angle of the ecliptic. Both axes intersect each other in a centre about 12ft above the floor, which is also the centre of gravity for the whole complex of projectors. Therefore it is easy to tilt the whole apparatus on a horizontal axis which goes through this centre in order to give the pole axis each desired inclination to the horizon. In this way the demonstrator is able to show the sky for different latitudes from the north pole to the south pole during one lecture. The horizontal axis is supported by a stage of framework which had to be designed in such a manner that it should not greatly disturb the passing rays of the projectors.

The spherical diameter of the dome for this planetarium can be chosen within a wide range. Domes have been constructed from 60ft to 100ft in diameter. The cost of the building exceeded the cost of the instrument in almost all cases. The construction of the instrument itself is practically the same in all these planetaria. We had no reason to alter the fundamentals of the construction. Even now, although we have prepared a new mechanism for showing, in addition, the proper motions of the fixed stars as far as these would be clearly visible during an epoch of about 100,000 years both in the past and the future, the result will be a supplementary apparatus which will be attached to the universal instrument with only small alterations.

(To be continued)

Electric Welding Plant and Electrode Factory

A new works has been opened by the Lincoln Electric Company, Ltd., at Welwyn Garden City, Herts, about a mile away from the original factory where the firm first started production of electrode and welding equipment some twenty-one years ago. The new factory covers an area of 190,000 square feet, and its considerably greater production space is expected to cover the firm's manufacturing requirements for some time to come. It comprises a main single-storey production shop which is linked to a two-storey office and laboratory building by a 12,000 square foot building providing accommodation for a training school, an electrical development shop and a canteen.

The main production shop is built on the "Arcon" prefabricated system and comprises six 500ft by 50ft bays. It is divided into three main production departments concerned with the manufacture of welding fluxes, electrodes and welding machines. The general flow of production is down the length of the building and a road passing through the shop at each end gives direct access for vehicles to the ends of the production lines for the delivery of raw materials and collection of finished materials and equipment.

In the flux manufacturing department materials are drawn from the stores area and delivered into the boot of an elevator and transfer conveyor system which delivers into a group of elevated bins on one side of the shop. The required amount of each material for a particular flux composition is deposited through valves in the bases of the bins into the hopper of a batch weighing equipment which runs on rails beneath the line of bins. The batch weigher then traverses to the end of its track and deposits the batch into a tumbler mixer. At the conclusion of the prescribed mixing periods the batches are deposited into oil-fired or electric furnaces, where the materials are reduced to a molten state. The electric furnaces installed are of twin-chamber construction with one electrode head serving two chambers. With this arrangement the materials in one chamber can be heated whilst the other chamber is being emptied and recharged.

The molten material is poured from the furnaces into quenching water tanks, where instantaneous cooling renders it into pellets. These pellets are then dried in an overhead rotating kiln, from which they pass on to screens where oversize lumps are passed out for crushing and fine dust is removed. The flux is then packed and sealed in steel containers ready for delivery. Flux for the electrodes made in the factory is batched and mixed in an adjoining section of the department.

In the electrode making section wire in coil form is drawn from the stock piles at the head of the line and delivered to a group of machines, where it is straightened and cut to the required electrode rod lengths. These rods are then transferred to the magazine of an electrode coating machine. From this magazine the rods are delivered in a continuous line through an extruder head, by which they are coated with the required thickness of flux. As the electrodes pass from the extruder head of the machine they drop on to a conveyor which carries them past a rotating brush which removes a short length of flux from one end. They are then carried on through a drying oven, whence they fall on to a packing table for loading into canisters which are hermetically sealed when full. Electrodes made in small numbers are made on individual machines and dried in ovens.

In the welding plant manufacturing department flow-line production and assembly methods have been introduced, with a final testing section immediately adjoining the despatch road at the lower end of the shop. In the future this department will also manufacture all accessories complementary to the welding machines, including electrode holders, ground clamps, &c. Plans are also in hand for the future introduction of sections for making welding rotators, manipulators and other ancillary welding plant. The plant department is also responsible for a comprehensive overhaul and maintenance service available to users of Lincoln equipment.

Five well-equipped laboratories have been included in the new factory plan and they are fully engaged in the maintenance and improvement of the quality of the firm's existing products, the development of new products, and investigation into welding problems submitted by clients. A close laboratory control is maintained over all stages of production in the works to ensure adherence to manufacturing specifications and the suitability of the raw materials used. A new department of the firm is the electrical development section which will be responsible for the development of prototype machines and new equipment, both for use in the factory and for production.

Institution of British Agricultural Engineers

The twelfth annual report of the Institution of British Agricultural Engineers shows that membership of the Institution had reached a total of 1375 by the end of 1956. About the Institution's educational activities, the report records that, last year, forty-five candidates sat for the National Diploma in Agricultural Engineering examination and that twenty-seven of them passed. The Johnson Medal for outstanding merit was awarded to Mr. C. de B. Codrington. The report goes on to say that, in the opinion of the examiners, "the standard attained by candidates was, on the whole, in advance of that reached in previous years." In particular, the examiners were gratified to note that the standard of English used and the presentation of answers showed a distinct advance on those of 1955. There is also reference in the report to the progress of the Institution's six local centres, and to the fact that, last year, the first of a series of "study group" reports was published. This document, which deals with the important question of safety in the operation of agricultural machinery, was originated by the East Anglian centre and is based on exhaustive investigations made in the area covered by that centre.

It is of interest to recall that a decision to form the Institution was taken at a meeting of a small group of agricultural engineers towards the end of 1938. A provisional council which was then appointed kept the organisation in being throughout the war years, and since 1946 there has been continuing progress in the Institution's work of encouraging the general advancement of all those aspects of engineering which apply to agriculture. One of the Institution's main objects is to raise and protect the professional status of agricultural engineers and to provide qualifications which will be accepted at home and overseas.

At the annual general meeting, which was held in London on May 6, Mr. J. M. Chambers, M.I.Mech.E., technical director of Massey-Harris-Ferguson, Ltd., was elected president in succession to Mr. D. R. Bomford, who has served for two years in that office. The annual meeting was followed by a well-attended luncheon at which the principal guest was Sir Alexander Glen, secretary of the Department of Agriculture for Scotland.

Torque Converter Roller.—Eddison Plant, Ltd., has built the prototype of a batch of road rollers with hydrokinetic transmissions for use in its hire fleet. Weighing 8 tons or 9½ tons with sand ballast in the rollers, it is driven by a Ford diesel engine with the automotive fuel system, including a pneumatic governor. A Brockhouse turbo-transmitter drives through an epicyclic gear giving ratios of 2·3 forward and 2·35 reverse: either gear can be engaged by oil-operated band brakes regardless of the power setting. Mechanical hand and foot brakes and manual steering by worm and sector are used. For long endurance on contract hire a total fuel capacity of 75 gallons is built in, with hand pump transfer to the 25-gallon ready-to-use tank; 80 gallons of water for the roller sprinklers are carried, the gravity tank being filled by another hand pump. The cab is built in one piece from glass-reinforced resins and is easily removable. The roller has a maximum speed of 5 m.p.h. and a rolling width of 6ft 3in.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

TRACTION ENGINE RAILWAY LOCOMOTIVES

SIR,—Having some interest in this subject, and noting the comments made by Captain A. T. Lambert in his letter of April 23, may I add a small contribution ?

I remember Captain Lambert's uncle, "Ben," I believe. He was a year or so my junior. I, too, served my apprenticeship at Aveling and Porters, of Strood. I remember his grandfather, too, and his like are rare. My impression agrees with the hundred mark. There was another lime and cement works opposite to Peters, named William Lee, Son and Co., who used the single-cylinder type between works and chalk pit, and in my youth ordered one of the two-cylinder type. Here I disagree with Captain Lambert, who says that the principal difference was, apart from cylinder arrangement, the addition of a second flywheel. Maybe there were such, but the old single-cylinder engines were real traction engine shape—two small leading wheels under the smokebox, and two six-footers beside the firebox. I have stood in the cab of one of them and easily touched the face of the driving wheels. On the other hand, the two-cylinder type had four equal-sized wheels, driven via a common spur intermediate wheel from a sliding spur pinion on the crankshaft. While these locomotives were working the pit, the company had one locomotive on the works, for shunting lime and coal trucks to the railway sidings some little distance out. She was a square platform—vertical boiler placed centrally therein, and a two-cylinder inverted engine at one "end," driving a crankshaft with spur gear on to one main axle, the other being driven by coupling rods. The driver's pit was at the other end, with a coal bunker at the "corner." Water tank was across the engine end, and the boiler was fed via a donkey pump. The whole was roofed and valenced with sheet iron, and, as my recollection tells me, she was kept bright and clean. I rode the footplate of that locomotive when I was four or five years old. She was known as "The Busybody." I have a photograph. When she was scrapped (which was a shame, for she was a museum piece) the company transferred one of the old single-cylinder pit locomotives to the works after sending her to Avelings to have her face lifted, i.e., the buffers raised to the level of main line tracks, so much higher than the pit wagons. The result was amusing, for the buffer plate came across the centre line of the boiler. I have a photograph.

In later years, when British Portland Cement built their huge eyesore at Holborough, one of the directors was connected with the old Lee family. He ordered from Avelings one of the two-cylinder four driving wheels, regarded then as obsolete, not for sentimental reasons only, but because he knew the worth of the type of locomotive in chalk pit work. If a lump of chalk happened to be on the track, the old lady just shouldered it aside. If one of the Barclays met a similar lump, the chalk got crushed, but the side rods did not like it one little bit.

Unlike Captain Lambert, I was out of Kent after my apprenticeship for many years, but, returning in 1922, it gave me pleasure in the twenties to see my boyhood friends still at work here and there.

The road locomotive—yes, but the railways type—each built to order, I am surprised that as many as 105 have been traced.

STEPHEN B. FLETCHER, M.I.Mech.E.

Maidstone, Kent,
May 9, 1957.

TERMINOLOGY IN GEARING

SIR,—Dr. Tuplin suggests that as the term pitch circle cannot be restricted to a single meaning the only safe measure for the future is not to use it at all. He says that in British Standard practice what we all know as the standard pitch circle is called the reference circle. That may be British Standard practice ; but it is not standard British practice or standard practice anywhere else as far as I know. The reference circle is usually understood as a proof hub on a hob, cutter or gear for checking runout. The craze to be different will ultimately strangle itself.

The notion that an involute gear has no pitch circle until it meets its mate is quite old ; it has been expressed by Max Maaq, lecturing to the Technical Society of Winterthur in 1917 ; by Earle Buckingham in *Spur Gears*, 1928 ; and by others. By pitch circle, all were thinking of the operating pitch circle. Another view of the matter, put by Allan Candee, is that the operating pitch circles change with change in centre distance ; in effect, an individual gear has an infinity of operating pitch circles waiting to be called upon. We were taught in distant childhood that this valuable property (among others) was responsible for the rise of the involute at the expense of the cycloid which Dr. Tuplin wishes so ardently we would forget.

For brevity in speech and writing we often cut out the apparently superfluous word. Pitch cone distance in bevel gears is now cone distance with no loss of meaning. But pitch circle, without qualification, is usually intended to mean operating pitch circle, and if this distinction was regularly made all confusion would vanish. This is one example of a small saving bringing no overall advantage. I would define a standard gear as a gear cut with a standard hob to a depth where circular thickness and circular space are equal, where the axis of symmetry of the rack is tangent to the standard pitch circle, which is fixed by the pitch of the standard hob and the number of teeth in the gear. The base (pitch) circle depends on the pressure angle of the hob. If the gear is corrected by radial shift of the hob, so that the equality of thickness and space is disturbed, the standard pitch circle lives on, because the hob pitch has not changed ; so does the base circle, because the hob pressure angle is the same.

So that in any given gear, standard or corrected, there exists a standard pitch circle, a base circle (both fixed by the standard hob) and an infinity of operating pitch circles, one of which may be the standard pitch circle if the gears are on standard centres. The operating pitch circle is the only variable, and it adjusts itself automatically to the designed centre distance or changes therein. In the case of a central gear surrounded by others it is possible to have several operating pitch circles on the central gear at the same time.

Dr. Tuplin says that "In different circumstances one gear may have different meshing circles, but the consequent uncertainty is of no practical importance, as it is not necessary to consider meshing circles in design, manufacture, inspection or operation." If I had made such a statement, even prefaced by "in my opinion," I should expect to be jumped upon by a thousand heavy feet. If we substitute operating pitch circles for meshing circles, taking care we know the conditions at those circles, there will be no uncertainty. In production, the machine operator has to use a given hob and blanks supplied ; the only control he has is depth of cut ; the only thing he works by is tooth thickness. We must give him tooth thickness dimensions in one form or another ; and to write this down we have to make an allowance for the desired backlash. And where is the backlash figured ? At the operating pitch circles. This is where we came in.

Incidentally, we could use the term base pitch circle, from the base pitch ; but long usage has decreed otherwise, and base circle it remains. And if pitch circles are to go, what happens to that useful little peg to hang things on, the pitch point ? In bevel gears we have only one pitch circle, taken, by convention, at the large end, and unaffected by correction.

Change for the better is good, but no one should strongly advocate a change unless all its implications are carefully weighed. The fancy term "addendum modification" as a substitute for "correction" immediately suggests tip easing, and some may take it for that. It is possible to correct a gear without altering its addendum, by topping ; the only certain thing about a corrected gear is a change in thickness or space at a given radius. Dr. Merritt gave a lucid explanation of the process in "Simplified Design of Corrected Gears" (*Machinery*, March 29, 1934), and coined the term correction coefficient. The correction k is simply the shift of the rack for 1 D.P. or module. The original idea, from whence the word came, was correction for undercut in low-numbered pinions ; that is still necessary, and the fact that the process has been extended does not seem to justify losing its identity.

Mr. Lindsay wants to know how to get base diameter and base pitch without first calculating the standard pitch diameter ; $D_b = N \cos \phi / P$, and $p_b = \pi \cos \phi / P$, in the terms already known, N, P, and ϕ.

A. M. GUNNER

Hampton Wick, May 1, 1957.

Book Reviews

Automation and Social Progress. By S. LILLEY, M.Sc., Ph.D. Lawrence and Wishart, 81, Chancery Lane, London, W.C.2. Price 21s.

THIS book is concerned much more with sociology than with engineering. Nevertheless, engineers, and particularly those in management positions, would do well to read it. Dr. Lilley freely admits pro-Russian sympathies and partisanship with the British very-Left wing. This attitude may annoy many of his would-be readers—at times we found it somewhat irksome. On the whole, however, the book is lively, well written and good tempered. It states a case with which one can disagree if one feels so disposed. It is uncompromising and emphatic, but has the virtue that it seems to be an honest statement of the writer's convictions. Dr. Lilley gives this as a provisional definition of automation—" the introduction or use of highly automatic machinery or processes which largely eliminate human labour *and detailed human control*." The italics are used, by him, to differentiate between automation and what he terms " mere mechanisation." This theme—the elimination of human labour in the modern industrial establishment—sets the keynote of the book. Most of the other advantages of automation are ignored.

Dr. Lilley is not an engineer. This is revealed by curious little slips in what is, otherwise, excellent reporting in Chapter II, " The Pre-History of Automation," and Chapter III, " Automation Today." They can, however, be forgiven since his work is not primarily addressed to engineers, but to those interested in the social outcome of automation and, it would appear, particularly to labour leaders, industrial managers and politicians. Some of the references are not quite as accurate as could be desired. This would be merely hair-splitting if it were not that a book which issues such challenges to capitalist societies, and which bases those challenges chiefly on evidence culled from the U.S.S.R., should not be suspect in any detail of that evidence. The reporting on the Russian scene which Dr. Lilley gathered at first hand is illuminating. Recent articles in the British technical Press support the author as to the scope and variety of production engineering in the U.S.S.R. One interesting item is the explanation given to Dr. Lilley as to why the Russian Government entertained such a very difficult proposition as the automatic production of motor-car pistons which start as ingot and leave the factory finished, greased, wrapped and packed. And, likewise, the automatic production of ball bearings. Put very briefly, the Russians claim that they adopted these difficult tasks because such " all-out " projects " *would force them to master the automation of practically every basic process in engineering production.*" In short, they claim that it was a " considered policy " to deal with large issues rather than to adopt (in respect of these articles) the more normal step-by-step procedure.

Chapter IV is devoted to descriptions of possible automatic factories. The author says that it " will necessarily be a mixture of sober extrapolations from present trends with speculations verging on the realm of science fiction." He suggests " a sufficient supply of grains of salt to take with the latter." Nevertheless, the chapter is reasonably sober in its outlook. In a section entitled " A New Philosophy of Production " there is a well-presented argument for rethinking in design to suit the automatic process. " New Powers for Good or Ill " is the heading for Chapter V. The argument is summed up in the penultimate paragraph. " Automation puts in our hands immense new powers that could be used to improve realistically and rapidly the conditions of our lives, but which could equally be misused to produce the opposite effect. It is no use pretending to ourselves that because there is plenty of potential good in automation therefore good will automatically result. History gives too many examples where new tools were misused very seriously before men learned how to use them properly."

From this point on the book becomes more and more tendentious. In considering " Automation in our Economy " the capitalist system is definitely the prisoner in the dock. The recent difficulties of the motor industry are quoted to show the possible evil effects of automation, but the argument is too much influenced by the author's political bias to be really objective—it is not, in fact, a complete story. In " The Way Forward," we are invited to consider, further, the advantage of a socialist society. It commences with an acknowledgment that " capitalism was a progressive system in its early days—better than anything that had gone before . . . but despite its vigorous and constructive youth, capitalism in its old age limps—limps more and more as the years pass by. And automation adds a little more to the increasing incapacity of the invalid." The author admits that redundancy and unemployment will not arise from automation as such, but will come " from the attempt to use automation in an economy that does not have the right machinery for dealing with sweeping technological advances smoothly and for fruitfully employing great increases in productivity." The recommended remedy is the adoption of a planned economy promoted by a socialist state—presumably on the Russian model. In the summer of 1955, when Dr. Lilley visited Russia, he " talked to all types of people—factory directors, research engineers, production engineers, chairmen of factory trade union committees and men in the shops " . . . " all answered unanimously that they believed that their economy makes unemployment impossible."

After quoting at length from the Russian Sixth Five-Year Plan and the directives devoted to " mechanisation and automation," the author remarks that " the past history and future plans of the U.S.S.R. give us some idea of what automation can do, in the right social conditions, to make life a fuller and a better thing." He is of the opinion that if the capitalist system were abolished in Britain, we could do far better than the U.S.S.R. Meanwhile, we can help ourselves by encouraging East–West trade ; extending credits and loans on longer terms, and by reducing military expenditure. Well, there are many Right wing employers who would be only too willing to adopt these measures if the road were clear : but, for instance, what guarantee is there that, even if we adopted socialism *a la Russe*, the threat of war would be eliminated ? . . . unless, of course, we were content to become a satellite of the U.S.S.R. There is much more in Dr. Lilley's story than can be indicated in this brief review, but the main contention is that automation is, in a capitalist society, bound to lead to unemployment, and the only way to avoid this is to get rid of capitalism. The book is worth reading if only for ammunition to combat dangerous theories, but we are of the opinion that it has other matter for those interested in automation.

As to the format, it is well produced. The index is adequate. It is a pity that one of the four pages of illustrations—a diagrammatic representation of the Soviet piston plant—is badly reproduced.

Stress Corrosion Cracking and Embrittlement. Edited by W. D. ROBERTSON. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 60s.

COLLECTED together in this volume are fourteen papers communicated to the Symposium on Stress Corrosion Cracking arranged by the corrosion division of the Electrochemical Society in October, 1954. Eight originated in the United States, four came from England, one from Canada, and one from Germany. They cover a wide range of stress corrosion phenomena in aluminium alloys, magnesium alloys, austenitic stainless steels and mild steel. Two papers deal with the occlusion of hydrogen in steel and its harmful effect on ductility. Others deal more generally with the phenomena and mechanism of stress corrosion cracking. All the authors realise the need for a fundamental study of the mechanism of the type of cracking in the materials with which they are dealing. The great variation in the relative importance of electrochemical, mechanical and structural factors in the production of cracks in different alloys gives rise to conflicting ideas and makes generalisation difficult : so that any conclusions regarding a precise mechanism of failure usually apply only to specific alloy systems. Meanwhile, in the study of a particular alloy and environment, field, service and *ad hoc* laboratory tests continue to be useful. The importance of the subject is emphasised by the fact that with many materials stress corrosion cracking has become a limiting factor in design : and this symposium reflects the increasing interest which is being taken in the fundamental aspects of the phenomena involved.

Proceedings of the Third International Congress on High-Speed Photography. Edited by R. B. COLLINS. Butterworth's Scientific Publications, 88, Kingsway, London, W.C.2. Price 70s.

THE Third International Congress on High-Speed Photography took place in September, 1956, in London, under the auspices of the D.S.I.R. In the present publication are assembled the papers presented at the conference ; as only papers not previously published were accepted, the techniques and applications described are not otherwise available in print. In conjunction with the Congress, an exhibition of apparatus and materials was held and aroused much interest, as did a number of films produced by the various techniques of high-speed photography. Both the exhibition and the films are reviewed in the " Proceedings."

Books Received

Géométric Appliquée. By R. Beurrier. Dunod, 9e, Rue Bonaparte (6e), Paris. Price Fr.480.

Tin Box Manufacture. By J. W. Langton. Canning Publications, 14–15, Coleman Street, London, E.C.2. Price 30s.

A Handbook of Softwoods. H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 8s. 6d.

Machine Drawing. By Deane Lent. Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, London, W.1. Price 63s.

Brennhärten. By H. W. Grönegress. Vulkan-Verlag Dr. W. Classen, Haus der Technik, Essen. Price DM.9,60.

Thermodynamics. By Franklin P. Durham. Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, London, W.1. Price 55s.

Kinematics of Machines. By R. T. Hinkle. Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, London, W.1. Price 45s.

Research Centre at Lincoln

Fig. 1—This view of the high-speed engine section of the centre shows how the engines under test are arranged on one side of the bay. The remainder of the floor space is available for the setting up of test rigs for fuel pumps, valve gear, gearboxes, &c. Altogether, forty high-speed engines can be accommodated. In the foreground of the engraving the smaller engines can be seen. Engines up to 78 b.h.p. can be tested in this section. The power developed by the engines can be absorbed according to requirements by water-brakes, alternators and d.c. dynamometers

Fig. 2—The medium-speed engine bay is arranged in a manner similar to that of the high-speed engine section. Five engines up to 540 b.h.p. can be accommodated and there is room also for four engines of 1340 b.h.p. to 2410 b.h.p. The power developed is absorbed by dynamometers and alternators and electrical power generated can be fed back into the grid supply. Not all the development work of the firm on engines of this character has been transferred to this bay. It is more economical to carry out some of it on production test beds. But the basis of work later carried out on production test beds is initially investigated here

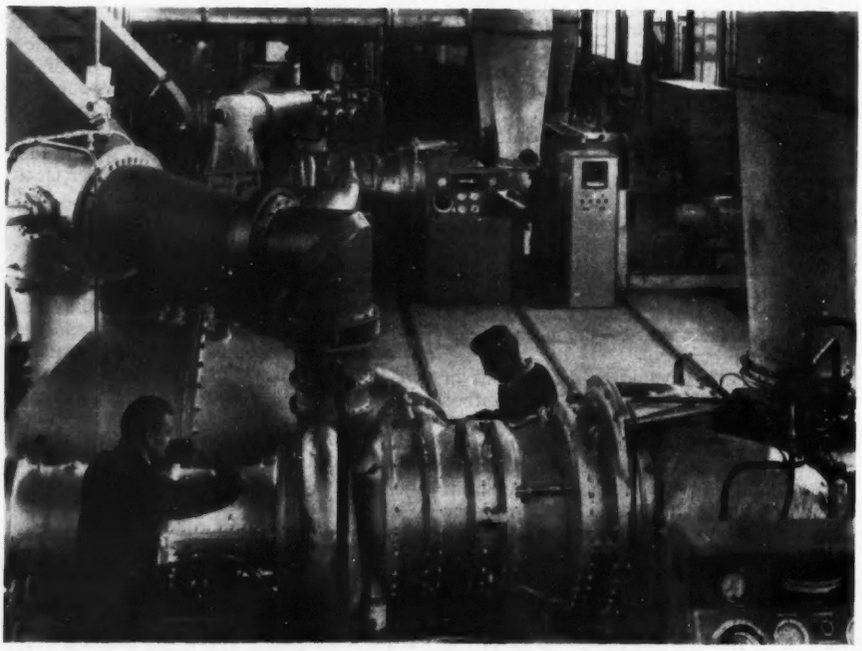
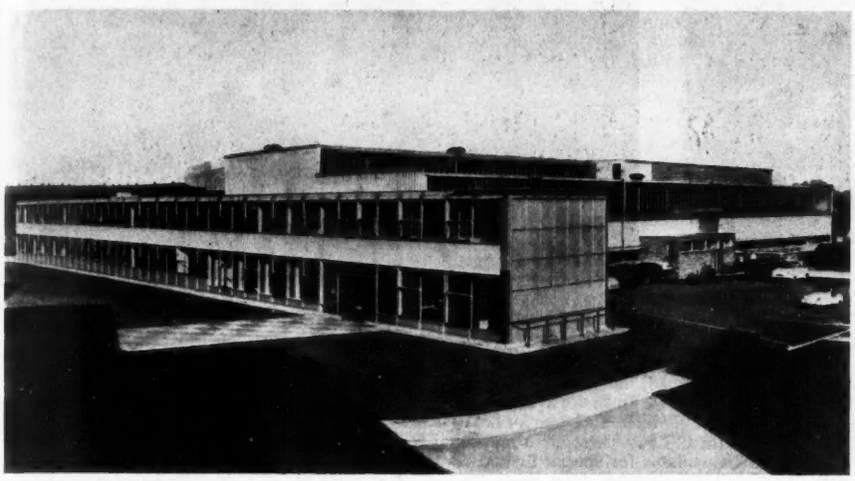


Fig. 3—Two gas turbines on test are seen here. The bay has, however, been designed to accommodate five turbines and when the centre is expanded there will be room for seven. The arrangement is notable for the fact that as many as four different types of fuel are available at each test bed. Air for the turbines is drawn in through filters at roof level and exhausted at a high level through a single vertical stack on the opposite side of the building. In this way the troubles experienced elsewhere with the contamination of turbine intakes by exhaust gases have been avoided. Power developed can be absorbed electrically in water resistance tubs or, if long-term running is envisaged, as where corrosion or blade failing tests are carried out, it can be fed back into the grid system.

Hydraulic dynamometers can also be used

Internal Combustion Research Centre at Lincoln



The new Research Centre of Ruston and Hornsby, Ltd., of Lincoln, is described. This centre came into use very recently and is not yet quite fully equipped. It is set out to permit research and development work to be carried out on the full range of the firm's engines and gas turbines and it is envisaged that eventually research upon small nuclear reactors may be done there. In addition there is space available for the erection of test rigs of various kinds and there are laboratories for carrying out more fundamental researches into stress analysis, fatigue and vibration. It is very probably the finest research centre of its kind in Europe.

LAST week we had the opportunity to visit the research centre that has recently been brought into service by Ruston and Hornsby, Ltd., of Lincoln. In plan the building, seen in the engraving above, is U-shaped. The base of the U contains a variety of small laboratories, offices for the staff, conference room, &c., and the two arms, each much wider than the space between them, contain the engine testing and other facilities. Through a structural, but by no means obvious, separation of the office and laboratory block from the rest, through the use of separate foundations, and through the liberal use of sound absorbing materials, the transmission of noise and vibration from engine test beds to the offices has been almost entirely prevented. No further references need be made to this block both because its laboratories are not yet fully equipped and because when equipped there will be nothing particularly notable about them. They are intended for carrying out stress analysis investigations, fatigue testing of small components, vibration investigations and the like, and for the study of a variety of problems likely to be encountered in the development of engines and gas turbines. The chief interest of the centre lies in its facilities for the testing of engines and turbines and full-scale or large-scale components.

The centre is equipped to carry out research and development work on the complete range of Ruston diesel engines (at present up to 2410 b.h.p.), gas turbines, and locomotives and to undertake a variety of activities connected with prototype projects. The actual capacity in terms of test bed operation is forty high-speed engines (Figs. 1 and 4); ten medium-speed engines (Fig. 2); five (at present) gas turbines (Fig. 3), and various rail track gauges outside the building permit tests to be made on any size of diesel locomotive.

High-Speed Engine Section

The capacity for engines under this category is twelve beds for engines of 0·5 to 2·5 litres; fourteen beds for engines of 2·5 to 7·5 litres, and fourteen beds for engines of 7·5 to 13 litres. The power developed by the engines is absorbed by water-brakes, alternators, or d.c. dynamometers. A main supply for electric starting, instead of starter batteries, is arranged through busbar circuit. The main cooling and brake water supply has been arranged to give constant pressure in the system independent of the offtake by individual engines. Water is pumped from a cooling well to the engines and the hot water runs back along open trenches to a hot well, whence it is pumped through cooling towers on the roof and returned.

A test area of 105ft by 15ft has been allocated for testing fuel pumps, valve gear, gearboxes, and other rigs. The work of the section is concentrated mainly upon the development of new air- and water-cooled engines; trial of accessories and components on current production engines prior to their approval for use on new engines; the development of normally aspirated engines to pressure-charged versions and of engines with higher ratings; tests with low-grade fuels and lubricating oils of all types prior to approval; investigations into service failures of unknown origin; operation of field research trials.

Medium-Speed Engine Section

There are two test bays in this section: one to accommodate five engines up to 540 b.h.p., and the other with a capacity of four engines of the 1340–2410 b.h.p. class or five engines of any other group. The power developed by engines in this group is absorbed by dynamometers and alternators. High-voltage parallel switching gear has been provided to enable the alternator output from any engine in these two bays to be fed back into the grid supply. The capacity of this switchgear is 2000kW at 6·6kV, which is of large enough capacity to cover any medium-speed engine up to 2410 b.h.p.

The work carried out on these engines is directly concerned with the improvement of engine performance—particularly with mechanical reliability and economy consistent with combustion and pressure charging, tests for which are made in conjunction with performance test work. In this respect work is in progress to investigate the behaviour of alternative and new types of bearings desirable for higher engine ratings now under development. Experience gained with engines of current manufacture is used to establish design specification of new models. In this respect, considerable effort is devoted to the investigation of claims for improved engine efficiency by means of variations from the normal diesel cycle.

Much of the development work associated with the medium-speed range of engines is, for reasons of economy, carried out on production test beds, since the tests are, in the majority of cases, of comparatively short duration. These consist largely of pressure-charger matching, investigation into intercooled engine performance and performance on lower grade fuels, both to the specific requirements of customers. But the basis of work carried out on production test beds is investigated initially at the centre, although not necessarily on the same size of engine. For instance, tests using research facilities on a 480 b.h.p. engine employing residual oil resulted in the entire range of medium-speed engines being released for operation on this oil. Check tests on the first example of each engine size are, however, made on the production test beds as previously stated.

Cold and Hot Chambers

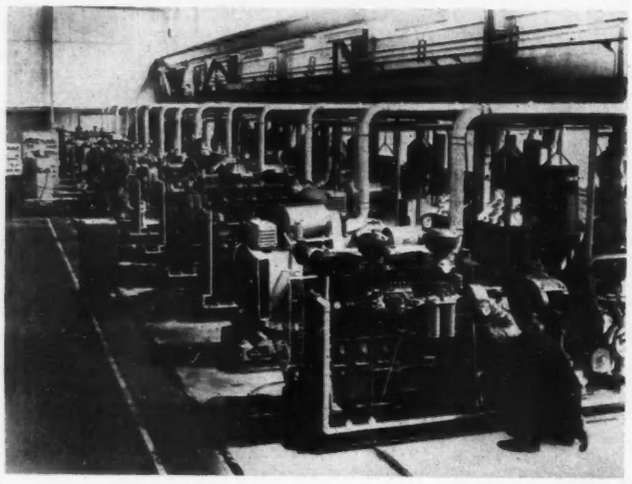
Prior to the establishment of the centre, cold starting tests were made in chambers owned by oil companies and C.A.V., Ltd. The demand on these facilities is high and the periods for which they are available are severely limited; the construction of a cold room (Fig. 5) in the new centre has allowed continuous development work to be carried out on cold-starting characteristics and the investigation of starting aids. Temperatures can be reduced to −40 deg. Fah.—the temperature specified for certain Ministry of Supply contracts. The cold room is equipped to indicate and record engine data such as starting speed, voltage and current drain from batteries for electric starting, lubricating oil temperature, air inlet temperature to the engine cylinders, in addition to the room temperature. The room capacity is such that four of the small, high-speed engines can be installed for simultaneous testing, but the capacity is clearly dependent upon engine size.

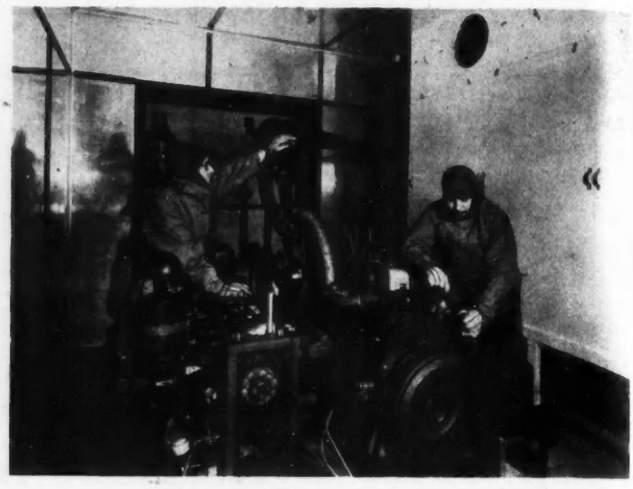
The equipment for this cold room is designed to produce a range of temperatures between −40 deg. and 35 deg. Fah. Interior cooling is effected by galvanised steel pipe coils with extended shaft fans and two condensing units driven by 6 h.p. motors. Two outlets are fitted on the roof—one for the exhaust fumes and the other acting as a form of valve to ensure that sub-atmospheric pressure is not created inside the cold room when an engine is in operation. Both outlets have insulated compartments. A large instrument panel is incorporated for use with recording apparatus of various types. The floor has been strengthened to withstand a weight of 4 tons.

The size of the hot room is 15ft by 14ft and it is capable of accommodating two of the small engines in the high-speed range up to 7½ litres or, alternatively, one engine above 7½ litres up to 13 litres capacity. Engines are installed in the hot room by removing part of the roof and lowering through the roof by means of an overhead crane of 5 tons capacity. Performance data is obtained at ambient temperatures between 90 deg. and 130 deg. Fah. Temperature control is achieved by means of thermostatic extraction fans, the heat being provided by the engine radiator in the case of water-cooled engines or by direct heat transfer in the case of an air-cooled unit. Engines under test are fully instrumented and remotely controlled.

Gas Turbine Section

It is claimed that every aspect of gas turbine development can be undertaken. Work now going on or contemplated relates to the thermodynamic and mechanical development of prototypes; the development of control systems; the combustion of various fuels; the investigation of prototype combustion chambers for new





Figs. 4 and 5—(Left) The test bay for engines up to 140 b.h.p. (Right) The interior of the cold chamber with tests being carried out on two vertical diesel engines. The temperature can be dropped to −40 deg. Fah. in forty-eight hours with an engine operating at maximum output

engines ; the aerodynamic testing of turbine components ; and the investigation of proprietary articles such as fuel and lubricating oil pumps, control equipment, &c. The turbine test bay has been designed initially to accept five turbines, although up to seven will ultimately be accommodated. At least four types of fuel are available at each test bed.

The air intakes to the turbines have been the subject of particular study ; the contamination of turbine compressor intake air by exhaust gases has, in the past, proved a trying problem on some research test beds. Air is drawn in from the roof level filter gallery. Various types of proprietary air filters are being fitted, both of the expendable and cleanable types, with a view to accumulating experience for future turbine installations in all parts of the world. Suspended from the floor of the filter gallery are the air metering venturis; in the case of the two beds allocated for smaller turbines, I.S.A. nozzles are fitted. The air passes through the turbine and is exhausted at a high level through a single vertical stack on the opposite side of the building. This arrangement allows most of the available floor area to be used and also enables reasonably stable ambient air temperatures to be maintained in the filter gallery.

For work in connection with the development of turbine control systems, the turbine is loaded electrically by means of water resistance tubs. These resistances, which are positioned beneath the high-level exhaust ducts, are so arranged that the complete range of loads up to overload can be accepted or rejected almost instantaneously. Where long-term running is envisaged, such as corrosion and blade fouling tests on a variety of fuels, the turbine can be run in parallel with the grid system. During such tests, the turbine carries the centre's electrical load, which would otherwise be taken from the grid. Synchronising panels and switchgear have been installed in the test bay close to the turbines. These electrical loading facilities are available at any one test bed. For thermodynamic performance work, hydraulic dynamometers are fitted, the necessary pressurised water supply and drain being available on all test beds.

Gas oil, residual fuel oil and coal tar fuels are available at each test bed, the last two mentioned being supplied from a heated ring main which feeds a pumping and heating unit situated near the turbine. Blast air for the atomisation of these two fuels is drawn from the gas turbine compressor at cycle pressure and fed into a small reciprocating compressor which boosts the pressure ratio to 2 : 1 before being fed to the burner. High-pressure bottled gas, i.e., methane, sewage sludge gas, &c., equivalent to half an hour's running time on a TA turbine at full load, is also available at each test bed.

Engineering Services

The principal point of note about the piped services is the variety of different fuels which have been laid on. The fuel storage area consists of five 50-ton tanks, the whole area being contained in a bund. Two tanks are available for gas oil, one for class "B" diesel fuel, one for heavy oil fuel and one for C.T.F. There are a number of smaller tanks available for special fuels used for the various turbine combustion rigs. The compressed air is normally shop supply at 100 lb per square inch. Ventilation is by Woods 24in extraction units, the inlet being by means of opening sections in the metal sashes of the vision strip.

Research in Progress

At the time of the visit, a number of researches were observed in progress and certain demonstrations had been specially arranged. Demands upon space forbid us to make reference to all this work and the following examples are chosen to provide some impression of the range covered.

A 6VEBC engine with Miller system of pressure charging is fitted with a de Laval 3 : 1 ratio pressure charger and a considerable amount of work has been carried out in investigating the possibilities of obtaining b.m.e.p.'s in excess of the standard production rating of 120 b.m.e.p. It has been found possible to reach 200 b.m.e.p. at a firing pressure of 1050 lb per square inch, which is the maximum allowable with this engine.

A 6VEB engine is being used for investigating main and large end bearing performances. It is known that the present standard white metal bearings as used in this engine are not capable of withstanding the higher bearing pressures associated with higher b.m.e.p.'s, and extensive tests have been carried out with copper-lead bearings in addition to promising tests now in progress on aluminium-tin bearings.

Fig. 6—Strain-gauge on a single-cylinder mock-up of a new type of engine

A research rig of a single-cylinder mock-up of a new type of engine is being used to investigate the structural stresses, structural deformations, and deflections, &c., when subjected to the simulated working loads. Use is made of strain gauges (Fig. 6). Tests are being carried out to obtain stresses at the various sections in the crankcase, cylinder block and cylinder head due to the tightening of the through-bolts and measurement of the structural deformations in the crankcase and bearings due to these loads. Tightening of the through-bolts is made by hydraulic tensioner units attached to each bolt beneath the crankcase. Hydraulic pressure is applied simultaneously to the tensioner pistons by a small reciprocating, hand-operated pump to obtain the correct tension. A locknut is provided to lock the bolt in the tensioned condition and the hydraulic pressure on the piston is then released. The firing pressure is simulated by hydraulic pressure applied on the piston whilst the inertia load is simulated by means of an hydraulic jack applying load at the bottom of the big end using a calibrated load-cell to monitor the load. The deformation and deflections of the structure are measured by means of a vernier travelling microscope, and dial micrometers with suitable linkages are adapted to measure the stretch—both of bolts and the structure—and main bearing deformations that occur.

Amongst other work in progress we noted equipment being used for the determination of torsional vibration in engine crankshafts and a 140 b.h.p. engine being used to carry out an endurance test on an isolator clutch for a mines locomotive. By electrical means the clutch is engaged and disengaged about every seven seconds. We also observed a prototype engine developed from the standard YB range running at 2000 r.p.m. It has a bore of 4in, a stroke of 4·125in and makes use of many of the components of the present YB engine.

Gas Turbine Work.—A demonstration was given of automatic control of a standard gas-oil-fired TA gas turbine, driving a 6·6kV B.T.H. alternator with a full load of 900kW. The programme of development of this control is now drawing to a close.

The engine is used for control system development and is fitted with the standard controls for gas oil running. This system consists of three main components :

A control unit, which in this case can be either manually or automatically operated. This unit controls the engine during the starting period, switching in the starter motor and igniter, and regulating the fuel flow to the burner until the alternator has reached full speed.

When the alternator has run up to full speed, the engine comes under the control of a centrifugal governor, driven from the output shaft.

Droop is normally set at 3 per cent for this engine, which gives an idling speed of 1545 r.p.m. and a full load speed of 1500 r.p.m.

An acceleration limiter is also fitted. This device controls the fuel flow when load is suddenly applied to the engine. Since this is a two-shaft machine, the compressor speed increases as the load increases. When a sudden application of load occurs, there is a temporary fall in output speed and the engine passes out of the control of the governor. The acceleration limiter then comes into action and controls the compressor acceleration until the output shaft once more approaches full speed and the governor takes over again. The limiter is set so that the engine can accelerate from idling to full load condition in ten seconds. When load is suddenly thrown off the engine, the governor reduces the fuel flow and also operates an electrical switch which energises two solenoid valves. These valves release the pressure in an air servo system. The removal of this pressure opens the four blow-off valves on the compressor delivery ducting, allowing excess air to escape while the compressor is decelerating down to idling speed. In this way, the increase in alternator speed when load is suddenly thrown off is reduced to a minimum. There are two mechanical safety devices : an overspeed trip releases the servo pressure, shutting the engine down if the alternator speed exceeds 1720 r.p.m., and a low lubricating oil pressure servo trip shuts the engine down if the lubricating oil pressure falls below 11 lb per square inch.

The starting equipment consists of a mechanical control unit and an electrical system of relays in a control cabinet. Operation of the equipment, both electrical and mechanical, is controlled by an electric motor driving a camshaft. Mounted in the engine control panel, the control unit consists of a motor-driven camshaft carrying eight cams working electrical contacts, and also a fuel cam. The fuel cam follower actuates a pilot valve and servo power piston mechanism, which regulates the fuel flow to the burner. During the starting period, the camshaft rotates through 250 deg. in ninety seconds. On shut-down, the camshaft rotates a further 90 deg. in the same direction, back to the start position. The eight electrical contact cams operate switches in correct sequence. This sytem of relays controls the sequence of starting operation and provides safety protection by means of various shut-down devices, each with its drop-flap indicator. The automatic control equipment is intended to give the following facilities :—

(*a*) Completely automatic starting and running up to predetermined governed turbine speed, initiated by push button or mains failure detection relay.

(*b*) Shut-down of turbine at any time, either during starting or running, by push button or mains resumption relay.

(*c*) Automatic shut-down of the turbine upon detection of lubricating oil failure, high lubricating oil temperature, high maximum gas temperature, starter motor contactor failure, flame failure, or control equipment supply failure during starting or normal running.

(*d*) The turbine cannot be started without sufficient lubricating oil pressure being available and the auxiliary lubricating oil pump is always brought into operation on shut-down taking place.

(*e*) After shut-down for any reason, the controls will revert to the conditions necessary for the next starting operation.

(*f*) Manual starting of the turbine, using the bare essential electrical circuits, should an emergency arise.

Another almost standard machine was seen running on CTF200 (creosote pitch). Features peculiar to this turbine include a refractory-lined combustion chamber fitted with an air-blast fuel atomiser, a heating unit to reduce the viscosity of the fuel to a level consistent with satisfactory atomisation, and a small reciprocating compressor necessary to boost the burner blast air to the desired level. Initially, starting of the turbine was carried out using CTF50 (creosote) and change over to CTF200 was effected after the engine had been started. Development has been such, however, that starting is now carried out on CTF200 only. The fuel, which is heated initially to pumping temperature in an outside storage tank, is pumped at low pressure round a steam-traced ring main serving both the rig and turbine test bays. Fuel is taken from this main to a pumping and heating unit which raises the temperature and pressure of the fuel to 200 deg. Fah. and 250 lb per square inch respectively. Difficulty has been experienced in pumping CTF200 fuel due to its abrasive nature and development is still being carried out in order to increase the pump life.

The major problem associated with the burning of CTF200 fuel in gas turbines, we learned, is that of finding a satisfactory refractory lining for the combustion chamber. Development work on this turbine continues in the search for refractories of superior performance to those at present in use.

The architect responsible for the office and laboratory block was J. C. Clavering, F.R.I.B.A., of London. The consulting structural engineer for foundations and structural frame of office and laboratory block was T. Bedford and Partners, of London. The consulting structural engineer for building foundations of the test area was Clarke, Nicholls and Marcel, London, W.2. The main contractor for the building was Wm. Moss and Sons, Ltd., Loughborough.

Ditch Cleaning Machines

In recent years renewed attention has been given to the maintenance of farm ditches as an essential factor in satisfactory land draining. A committee, presided over by Sir Arthur Heneage, produced a detailed report on land drainage in 1951 *which emphasised the necessity for the regular cleaning and digging out of ditches. The provision of machines suitable for that task has presented many problems to agricultural engineers and manufacturers of contractors' plant, but considerable progress has been made in mechanised ditch cleaning. The Royal Agricultural Society has recently concluded competitive trials of ditch digging and cleaning machinery and has awarded silver and bronze medals. The "Landrainer" illustrated on the right is one of the machines which has qualified for a silver medal award. Others are referred to in this article.*

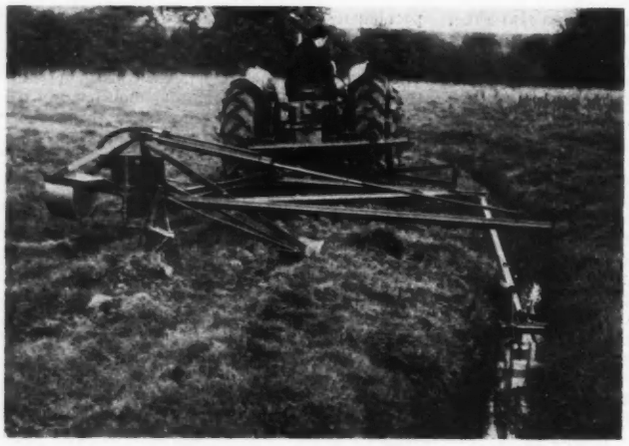
THE maintenance of farm ditches is a matter which is important to the business of adequate field drainage. As well as carrying away the water from tile drains laid across fields, ditches in many places also drain the land through which they pass. Field draining and ditch cleaning are jobs that have not always been regularly undertaken on the farms of this country. They are operations which were frequently neglected in times of agricultural depression, and it has been suggested* that from about 1878 to 1938, with few intermissions, there was increasing neglect of this side of farming. During the second world war, however, and in the immediate post-war years, it is estimated that ditching schemes affecting 5,250,000 acres of land were undertaken in England and Wales, as well as 400,000 acres of tile draining and 500,000 acres of mole draining.

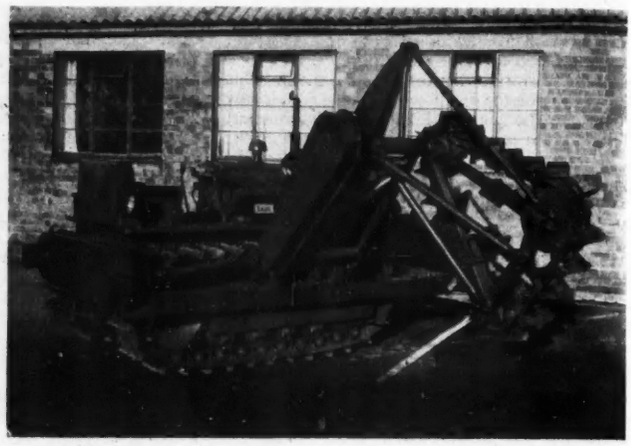
Some more up-to-date statistics as to the extent of the ditch maintenance problem are contained in a paper presented last year to the Institution of British Agricultural Engineers† by Mr. J. G. Bates. This paper says that there are approximately 186,000 miles of open ditch in England and Wales, of which roughly 13,000 miles are self-cleansing and require little or no attention, leaving 173,000 miles which need annual maintenance to prevent them from silting up. Up to the beginning of last year about 77,000 miles of the total length of ditch had been improved with grant aid from the Ministry of Agriculture. Recent surveys have shown that about 40 per cent of these ditches are being adequately maintained, 30 per cent partially maintained, and for 30 per cent there is no evidence of maintenance at all. Of the balance—approximately 96,000 miles—only about 2 per cent are being adequately maintained.

Agricultural engineers are now giving a good deal of attention to the development and production of ditch cleaning machines. Various designs are being tried out, including rear, front and side tractor-mounted jibs and scoops, and machines incorporating the endless bucket chain system, or a floating bucket dredger principle. In the majority of the machines now available the hydraulic system of a tractor is used for operating the jibs, scoops and spoil ejectors, and for the lifting and lowering of digging and grading attachments. Some of the machines are designed for working along a

* *Inst. Brit. Agricultural Engineers, Journal*, Vol. VII, No. 1.

† Ibid., Vol. XII, No. 2.





(Left) "Sapper" ditching machine at work; its maximum depth of cut is about 6ft. (Right) The "Lincol" ditch-cleaner incorporates the principle of the endless chain. The machine can work at a speed of about 880 yards an hour

ditch, while others—consisting generally of light jib attachments fitted with scoops—are operated by a tractor working at right angles to the ditch.

The importance of encouraging the design and improvement of ditch cleaning machinery has not been overlooked by the Royal Agricultural Society of England. Ever since it was founded in 1839, the Society has regularly organised competitions and conducted trials, the sole object of which has been to assist the improvement and increase the efficiency of all kinds of farm machinery. Last year, the Royal Agricultural Society announced that it would award silver and bronze medals for "mechanically operated appliances most suitable for cleaning farm ditches accessible from only one side." Fourteen entries were accepted by the Society for this competition. These machines were examined, on sites selected by the competitors, by the three judges, Lord De Ramsey, Mr. H. L. Drewitt, and Mr. E. A. G. Johnson, M.I.C.E. As a result of that preliminary examination, nine of the machines were selected for a final demonstration working alongside one another on ditches chosen by the judges. This demonstration was recently held at Abbots Ripton, Hunts. The ditches selected were 4ft to 5½ft wide at the top, and, in general, an 8in to 12in depth of sludge had to be removed.

Since the demonstration it has been announced that the Society has awarded silver medals for two of the machines and bronze medals for five machines. In some preliminary comments on the performance of the individual machines, the judges have said that they gave particular consideration to four factors, namely: ability to take a light cut as well as a heavy one; maintenance of a narrow ditch bottom and of properly battered sides; ability to place the spoil conveniently and to operate without excessive damage to field surfaces, and the mechanical soundness of the machines. The judges have recorded their opinion that "the ideal solution to the general ditch cleaning problem has still to be found."

Silver Medal Awards

The two machines in respect of which the Royal Agricultural Society has awarded silver medals are the "Landrainer," built by W. and G. (Challow), Ltd., Challow, Berks, and the "Unique" ditch cleaner, which is a product of Carter Bros. (Billingshurst), Ltd., Billingshurst, Sussex. The "Landrainer," illustrated on page 763 has been designed on the dragline principle, but without the use of winches and cables. A telescopic boom, controlled by a push-pull hydraulic ram, enables 5ft stretches of ditch to be dug or cleaned, with the tractor stationary. The machine is moved forward, 5ft at a time, by the tractor to which it is attached. The "Landrainer" is assembled on a tubular steel chassis and is hitched to the tractor by a drawbar pin. A tractor of about 40 h.p. is required, the only equipment which it is necessary to fit to the tractor being the hydraulic pump and oil tank. This pump supplies oil to the hydraulic system at 1000 lb to 1500 lb per square inch; it is driven from the forward end of the crankshaft by a special adaptor.

In all, there are seven hydraulic rams which are operated by a bank of control levers at the front of the machine, and within easy reach of the tractor driver. A spring-loaded relief valve is fitted to the hydraulic circuit to give protection against overloading. The sequence of operations includes the lowering to the ground of two sprags and the raising of the offside pneumatic-tyred wheel to hold the machine to its work. By varying the height of either of the sprags, or the position of the retracting wheel, the machine can be set at an angle either towards the ditch or away from it, to ensure that the bucket, when cutting, is always vertical. The telescopic boom is then lowered and extended to its full length and the bucket is tilted and dropped on to the face of the job. The spoil is taken up, the sprags are raised, and the wheel lowered, and the tractor draws the machine forward for the cycle of operations to be repeated. There is a counterbalance weight to correct any list of the machine caused by its side-digging action. This balance weight is directly linked to the pivot pillar and is moved automatically in relation with the digger arm. The "Landrainer" has a standard bucket, and the dimensions at which it normally digs ditches are, approximately, to a depth of 3ft 6in, with a bottom width of 1ft 3in and top width of from 4ft to 4ft 6in. The average working speed, allowing for two "cuts" on each 5ft stretch, has been found to be about 3 chains an hour.

The other "silver medal" ditch cleaner, that built by Carter Bros. (Billingshurst), Ltd., is an implement which can be attached to the hydraulic linkage of a tractor. It consists of a jib fitted with a bucket and, with the tractor at right angles to the ditch, the bucket is lowered to the far side of the ditch, drawn across and up the nearside bank. As the tractor moves forward, the spoil is spread, the bucket being automatically tipped for emptying.

Bronze Medal Awards

The machines which qualified for the Royal Agricultural Society's bronze medals have been described by the judges as "showing considerable promise, while needing further development." One of the machines in this group is the "Sapper" ditcher, which has been designed and put into production by Bomford and Evershed, Ltd., Salford Priors, Evesham. It is a "one-man" machine, operated by the driver of the tractor to which it is attached, and is intended primarily for cleaning ditches which are accessible from one side only. The machine can, however, be used also for opening new ditches. The construction of the machine is simple, there being a tubular frame carrying a pivoted hoist pole from which there is suspended an arm for carrying a 1 cubic foot capacity bucket. To the nearside of the pivot point there is a skid pan which takes the weight when the filled bucket is raised, and opposite to it there is a weighted bucket which acts as a counter-balance. Side thrust, when the ditcher is in operation, is taken on a disc wheel at the back of the frame. The machine is hitched to the drawbar and hydraulic lift arms of a tractor, and the bucket is operated by a single-acting hydraulic ram.

The tractor moves forward as the bucket fills; when the bucket is full the tractor is stopped, the bucket is raised and swung clear of the ditch, and by the operation of a trip wire is emptied of its spoil up to a distance of 9ft away from the ditch. The bucket is then automatically closed by the action of a spring and is returned to the ditch for the next cut. The machine can work to a depth of 6ft if required, and the makers have said that an average exceeding 5 chains an hour has been achieved in some of the ditch cleaning jobs that have been tackled recently. Incidentally, the machine can be assembled on a tractor to work either right or left-handed to a ditch; there are no parts which have to be permanently fixed to the tractor.

Another machine which qualified for a bronze medal award is the "Lincol" ditcher, built by Barford (Agricultural), Ltd., Belton, Grantham. As may be noted from the illustration above, this machine is side-mounted on a crawler tractor; it comprises an endless digging chain, which is lowered and lifted by a hydraulic ram. This digging chain, which is fitted with hardened tines, runs on idler rollers mounted on an inverted triangular framework. The frame can be adjusted to conform to various ditch sections. The drive is taken from the power take-off shaft of the tractor in two stages, and the ram for lifting is powered by a hydraulic pump mounted on the front of the tractor and driven directly from the engine crankshaft. The "Lincol" is a machine that comes within the category of contractor's equipment rather than that of agricultural machinery. It can operate to a depth of 3ft 6in. To put it into work, the tractor is placed about 4ft 6in from the edge of the ditch, and parallel with it, and the digging chain is then lowered until it is just touching the bottom of the ditch. The power take-off is then engaged and the digging chain rotated. The rotating chain is lowered until it is taking a cut at the required depth, and the tractor moved forward in bottom gear. At the recent R.A.S.E. demonstration, an operating speed of about half a mile an hour was maintained, the spoil being spread evenly between the edge of the ditch and the tractor.

Bronze medals have also been awarded for the "J.C.B." ditcher made by J. C. Bamford (Excavators), Ltd., Rocester, Uttoxeter, Staffs; the "Cumbrian" ditch cleaner made by Cumbrian Implement Company, Ltd., Aspatria, Cumberland, and for the "Whitlock" ditcher built by Whitlock Bros., Ltd., Great Yeldham, Essex. This last-mentioned machine was described in THE ENGINEER of December 7, 1956. All the machines in respect of which silver and bronze medals have been awarded are to be exhibited at the Royal Agricultural Society's annual show, at Norwich, in July.

Instruments, Electronics and Automation

No. II—(*Continued from page* 726, *May* 10)

An exhibition of instruments, electronics and automation was opened at Olympia on Tuesday last week and closes to-day It was clear from a tour of this exhibition that British firms are well able to develop methods of measurement and servo control which can expedite industrial production, particularly by economising in the expenditure of labour. It is equally clear, however, that many British industries, especially some involving smaller firms, make insufficient use of existing experience in instrumentation. Some exhibits at Olympia are described below.

Evershed and Vignoles, Ltd.

INSTRUMENTS and control equipment for process industries are being shown by Evershed and Vignoles, Ltd., Acton Lane Works, Chiswick, London, W.4.

The new products to be seen on the stand include the Evershed Mark 4 process controller. It is fully electronic and there are no moving parts in the controller itself. The three control terms, proportional, integral and derivative, are generated separately, and they are, therefore, free from interaction. The new controller has simple d.c. circuitry, and the great advantage offered by built-in test facilities. This new process controller operates in conjunction with a variety of Evershed measurement transducers covering almost any physical parameter, but in principle any transducer providing a suitable electrical signal may be employed.

The new Evershed computer which is on show is a simple analogue computing device designed to provide a continuous and instantaneous solution of algebraic equations occurring in the day-to-day operation of process controllers, boiler control schemes, and gas or fuel flow systems. The input information to the computer is an electrical signal which requires no programming or processing, and the output of suitable transducers, measuring devices or manually controlled signal sources may be introduced directly as variables in the input to the computer. Similarly, the computer output (that is, the mathematical evaluation according to a predetermined formula of the variables and constants) can be employed directly as an operating signal for electro-mechanical control mechanisms, &c. It can also be displayed on indicating and recording instruments if required.

Accordingly, the computer can be integrated into a process control scheme, evaluating continuously the variables and constants entering into the controlled process, and its output can be used to maintain the process as required. Alternatively, it can be used purely for the display of the solution of algebraic equations of dynamic problems. In the exhibition the computer is being demonstrated in a typical application to a flow metering problem.

Nash and Thompson, Ltd.

A ventilation network analyser and a shorted-turn detector are among the equipments shown by Nash and Thompson, Ltd., Oakcroft Road, Chessington, Surrey.

The ventilation network analyser (Fig. 6), which was described in our issue of July 17, 1953, page 71, is an analogue instrument designed to simplify the mathematical solution of non-linear network problems of the kind that may be encountered in the flow of fluids or, in particular, in ventilation systems. It is based on a laboratory instrument devised at Nottingham University as a result of research sponsored by the National Coal Board. It depends on the setting up of a network of linear electrical resistors exactly simulating the system to be studied. The electrical resistors are adjusted until the currents in them correspond to the fluid flows in the system.

The currents and pressure drops around the network are read on calibrated meters connected into circuit by means of jacks. The resistors on the instrument, which simulate branches of the system, are brought out to a connection panel, where they can be connected into a number of junctions. Power packs stabilised against mains supply changes are provided to simulate sources of pressure, e.g. fans, pumps.

Where the system requires it (for instance, in gas and water distribution), a separate panel is used incorporating a number of units which simulate loads taking constant flows regardless of supply pressure. These units can be connected into circuit in the same way as the resistors representing branches or sections of main.

The shorted-turn detector exhibited on the same stand provides a means for detecting a very small number of shorted turns in an electrical coil containing any number of sound turns. Its limit of sensitivity depends on the size of coil (for example, one shorted turn of about 42 s.w.g., at a winding depth of $\frac{1}{4}$in on a $\frac{3}{8}$in square coil, or one shorted turn of 40 s.w.g. at a winding depth of $\frac{1}{2}$in on a core of $1\frac{1}{4}$in square), regardless of the number of sound turns in the coil.

The test coil is mounted in a jig, whereby it is coupled to the tuned circuit of an oscillator working at a frequency of about 1 kc/s. The current thereby induced in the shorted coil causes damping of the oscillator, which can be detected as a change in the reading on a meter. By deliberately short circuiting the ends of the winding, its continuity can be checked, again as a meter deflection.

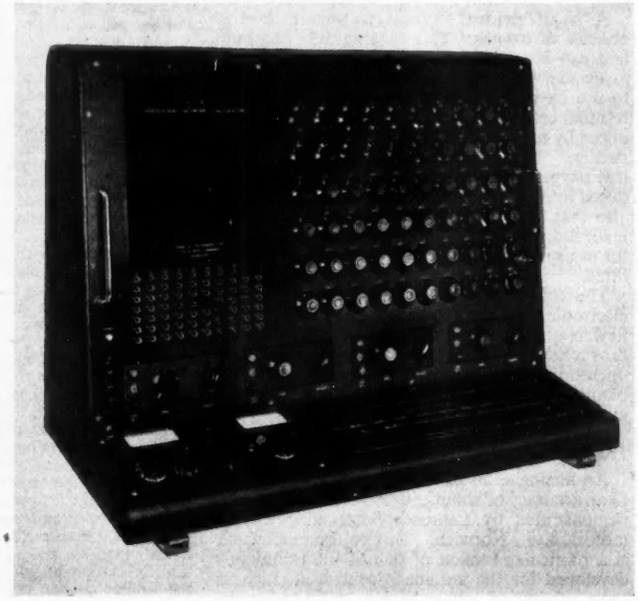


Fig. 6—Fluid network analyser for simplifying the solution of non-linear network problems, such as the flow in ventilation systems—Nash and Thompson

The instrument is housed in a small case which has a sloping front and measures $4\frac{1}{2}$in by 3in by $2\frac{1}{4}$in. The panel contains the indicating meter, a three-pin plug socket and two control knobs. A range of interchangeable jigs is available for plugging into the socket. A stack of laminations projects from each jig and the coil to be tested is slipped over this jig.

Ekco Electronics, Ltd.

Electronic control of the setting of an Elgar jig borer is being shown by Ekco Electronics, Ltd., Southend-on-Sea, Essex. This control system can be fitted to existing machines. It can set the rotation of a lead screw (or other rotating shaft) to within one-five-hundredth of a turn and the repeat accuracy on a 10 t.p.i. lead screw would, therefore, be of the order of 0·0002in.

Basically, the system consists of a traverse unit for each lead screw and a combined control unit for both traverses. The traverse unit consists of a drive unit and servo head which is coupled to the lead screw, through suitable gearing (after the handwheel has been removed), and is supported from the lead screw bearing bracket. No other modification is required to the machine unless sequential operation or automatic table clamping is required.

The fast traverse rate is a minimum of 24in per minute, but as a series motor is used this increases with low torque loadings. A low-speed traverse rate is used for the final approach to the rest position.

Manual control over the motors is provided by a push button which permits the table to be moved in either direction at full or "inching" speeds. Provision for turning the lead screws by handwheel is also made.

The servo head incorporates an indicator which shows the position of the traverse unit with respect to the settings on the control unit. This provision enables the operator to check that the traverse unit has, in fact, moved to the set-up position in the control unit. A direct indication in inches and decimals is therefore given of the position of the worktable with respect to a datum point. Datum shifting facilities can be incorporated in the servo head to enable the operator to use any part of the worktable as a reference datum.

A single control unit serves both traverses. There are six decade dials per traverse for setting up the digits of the co-ordinate, the number set being shown through a window above each decade knob. The control system consists of a series of Wheatstone bridges, the master potentiometers of which are set up to the desired measurement. The drive unit turns slave potentiometers in the servo head until voltages in the bridges are balanced out. The first three digits of a co-ordinate are sequentially selected by counters coupled to the slave potentiometers, which count the number of turns made by the lead screw. The last three digits are resolved by a slave potentiometer wound over 360 deg. This is set up by three master potentiometers to facilitate decade presentation for the complete ordinate.

The drive unit is part of a servo and stability is achieved by use of a slow approach speed to the rest position. The major part of the traverse is made by a $\frac{1}{3}$ h.p. motor controlled by the first three decades. The last three decades control a small motor for the final approach.

The traverse unit (Fig. 7) measures $9\frac{1}{2}$in by $9\frac{1}{2}$in by $4\frac{1}{2}$in high, and the control unit measures $15\frac{1}{2}$in by 12in by 12in deep.

On the same stand there is a working display of the new Ekco "N611" fluid density gauge, which consists of a gamma-ray measuring head and an "N565" indicator control unit. With this instrument the contents of a liquid container, such as a pipeline, can be measured without having access to the fluid. The equipment is shown in Fig. 8. The gamma-ray source is mounted in a shielded container on one side of the pipe or tank, and a pressurised ionisation chamber is mounted on the other side. The

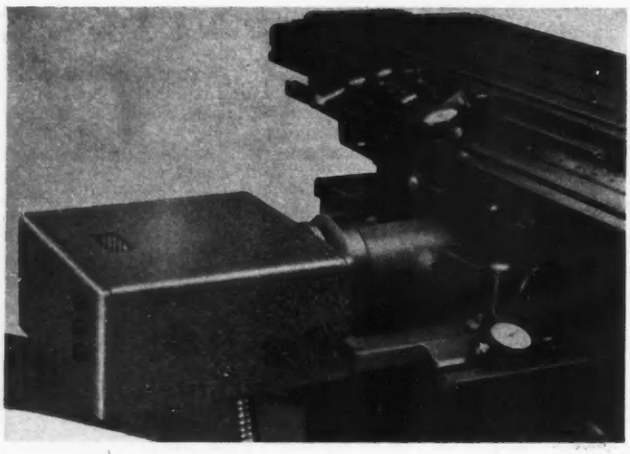


Fig. 7—Machine tool control with traverse units which will reset, for example, a lead screw, to within 1/500 turn—Ekco

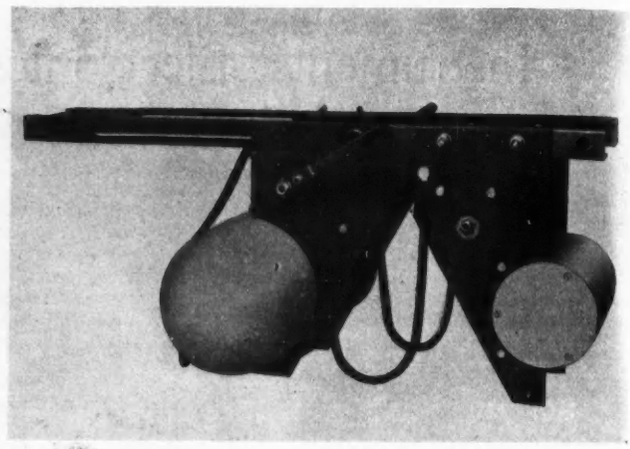


Fig. 8—Fluid density gauge consisting of gamma-ray source and ionisation chamber—Ekco

electrical output from the ionisation chamber depends on the density of the fluid in the pipe and the result is shown on the indicator/control unit. The indicator/control unit can be sited up to 100ft from the measuring head. Three versions of the measuring head are available : a separate ionisation and source holder for fixing to tanks ; separate ionisation chamber and source holder with straps for permanent fixing to pipes of 4in diameter and upwards; a transportable unit with a clamping device for quick attachment to pipes of 6in to 14in diameter.

Crompton Parkinson, Ltd.

An electronic speed controller for variable-speed d.c. motors on a.c. mains is being shown by Crompton Parkinson, Ltd., Aldwych, London, W.C.2. This equipment, which has been developed in collaboration with Airmec, Ltd., is arranged with a tachometer-generator and speed indicator to demonstrate speed variation on a ½ h.p. motor from standstill up to the maximum speed of 2800 r.p.m. The device (Fig. 9) makes

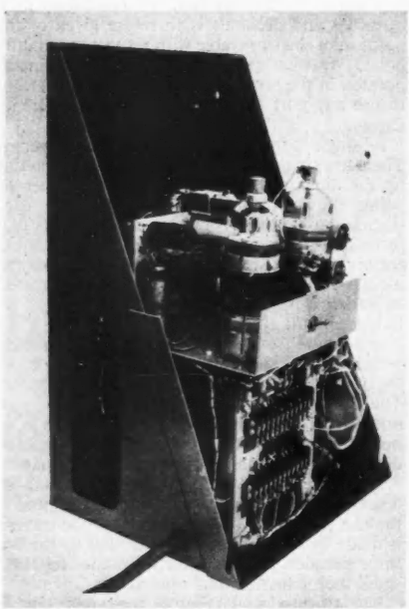


Fig. 9—Rectifier unit of electronic speed controller for d.c. motor on a.c. mains—Crompton Parkinson

use of a hand-operated bias resistor to vary the output of thyratron rectifiers and, accordingly, to vary the armature voltage and speed of the motor. The rectifier output is smoothed and the controller is provided with overload and no-volt protection and with facilities for dynamic braking and reversing. Printed circuits and plug-in assemblies of small components are used in the controller.

An overload trip for electrically driven plant is also being shown. It was first developed last year, but has since been modified and recently put on a standard production basis. It is essentially a sensitive, specially calibrated ammeter, which is provided with a pair of contacts that close at full-scale deflection to operate an external relay, the relay being used to control the machine. In use, the instrument is connected across the secondary winding of a current transformer through a potentiometer. The primary winding of the current transformer takes the operating current of the machine being controlled, and by simple hand adjustment of the potentiometer, the ammeter can be set to the appropriate overload value, thus avoiding the use of what could be a relatively fragile adjustable contact in the instrument.

Cambridge Instrument Company, Ltd.

An electro-chemical dissolved oxygen recorder is one of the instruments shown by Cambridge Instrument Company, Ltd., 13, Grosvenor Place, London, S.W.1, which is of particular interest because of the higher operating pressures in modern steam boilers.

The measuring element of the recorder is an electro-chemical cell consisting of two electrodes immersed in the conducting solution. The cell produces a current which is proportional to the concentration of oxygen dissolved in the solution. While it is not specific for oxygen, no other substances likely to be present in the boiler feed water and able to be transferred in a hydrogen stream have any significant effect on the current.

A small residual current is present in the absence of oxygen. This is practically constant and can be compensated by a zero adjustment associated with the recorder. It is not possible to use oxygen-free feed water to determine this residual current, but the same result can be produced by removing all oxygen from the hydrogen stream. The arrangement used for removing this oxygen will remove not only oxygen introduced into the hydrogen from the feed water, but also that introduced by leaks from the air. An independent method for checking for leaks and for measuring their effect on the zero is therefore fitted.

The equipment consists of an analyser unit, electronic recorder, control panel, mains unit, flow regulator, and water cooler. The kind of flow regulator and cooler depends upon the operating temperatures and pressures of the plant, and the temperature of the cooling water available.

Laurence Scott and Electromotors, Ltd.

An analogue instrument for measuring length to an accuracy of about ±0·0002in in 5in is being demonstrated by Laurence Scott and Electromotors, Ltd., Norwich. This equipment, which is a particular version of one of the techniques developed for the automatic control of machine tools, produces a voltage having a ratio to a reference voltage which is precisely proportional to the distance between an anvil and a probe. The length range of the instrument can be extended so that the tolerance quoted above can be maintained for lengths up to about 3ft.

Among the standard electronic equipments to be seen on the same stand are : a two-channel amplifier for controlling a resolver producing sine and cosine voltages of very high accuracy ; a three-channel feed back amplifier for impedance changing and adding ; and an electronic servo amplifier controlling either a split field motor or an exciter for industrial control.

Philips Electrical, Ltd.

An instrument for monitoring vibration on a power station turbine is demonstrated by Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2. It consists of a recorder, a vibration-level unit, and vibration pick-ups. The pick-ups produce a voltage proportional to the velocity of the vibration measured. After integration by means of an *R–C* network, this voltage—which is then proportional to amplitude—is amplified, smoothed and rectified, then fed to the recorder. An automatic selector switch enables sequential recording of up to twelve vibration channels.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

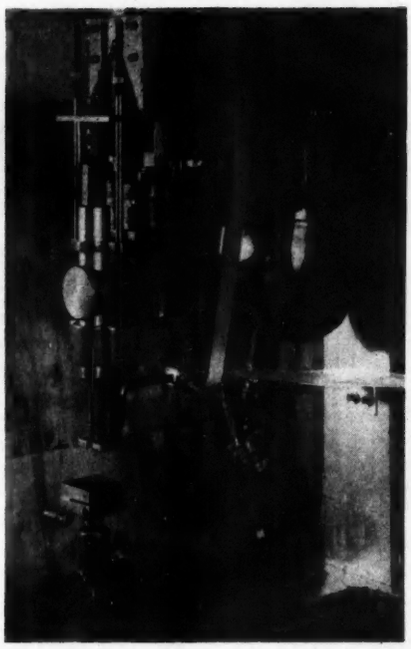
MOTOR STARTERS AND CONTROLLERS

No. 587 : 1957. Price 8s. This standard was first issued in 1937 and it has just been revised for the third time. The standard now applies to a wide range of different kinds of hand-operated and automatic starters and controllers as used with a.c. motors of rated voltage up to 11kV and d.c. motors up to 650V. Requirements for resistors and auto-transformers and similar equipment associated with motor control gear are also included. Standard ratings are specified on the basis of the main mechanical and electrical duties for which control gear is required, and standard sizes of starters and controllers are recognised in terms of motor horsepower. Full details are included of the standard duty ratings for resistors for use in motor control gear which have been generally recognised in industrial practice and in previous editions of B.S. 587. The design and constructional requirements deal with many aspects of control gear, including, for example, details relating to mounting, provision for earthing and earth continuity, preferred standards for push buttons and indicating lamps, undervoltage and overload devices, overcurrent and breaking capacities, &c. Limits of temperature rise for various kinds of contacts, conductors, coils, auto-transformer windings and resistors are specified. The type tests include main current heating tests, voltage tests on shunt coils and electrical performance and mechanical endurance tests. The routine tests comprise a high-voltage insulation test and tests on resistors, auto-transformers, voltage coils and overload devices. Seven appendices provide additional information on temperature measurement, clearance and creepage distances and resistor ratings, together with a graphical presentation of the maximum starting times for various motor starters. "Information to be supplied with an inquiry or order" forms the subject of one appendix. Another contains a summary of the special requirements for switching starters for a.c. motors of 1 to 25 h.p. The standard was prepared under the authority of the Electrical Industry Standards Committee.

Automatic Feeding Equipment for Nut Welding Machine

To reduce the time involved and manipulating difficulties experienced in positioning nuts whilst supporting panels on a machine used by Briggs Motor Bodies, Ltd., to resistance-weld small nuts on motor-car body panels, a special automatic "Weldnut" feeding equipment has been developed by Rhoden Partners, Ltd., 51, North Row, London, W.1. The 50kVA "British Federal" air-operated resistance-welding machine used for this work is shown in operation with the new equipment in the accompanying illustration. Before the feeding equipment was installed, the machine operator first had to locate the hole in the panel on a spring-loaded pilot pin in the bottom electrode of the machine. Whilst still supporting the panel he then had to place the nut on the pin and, by means of a pedal, initiate the electronically controlled welding cycle. With small panels this sequence of operations was not particularly difficult, but with large panels there was an appreciable time loss in the manipulation and balancing of the panels, and in placing the nut in position. There was also an element of danger in placing a nut between the electrodes by hand on a machine the working cycle of which was initiated by means of a pedal. These difficulties have been overcome by the automatic nut feeding equipment.

The nut feeding equipment includes a standard "Syntron" bowl feeder, from which the nuts are delivered one at a time to a pair of jaws carried by the upper electrode assembly of the machine. With this equipment a nut is delivered into the jaws immediately below the electrode each time it is fully raised. When the operator has placed the panel in position on the locating pin of the lower electrode he depresses the pedal to start the welding cycle. As the top electrode then descends it carries the nut in the jaws down with it until the nut contacts the panel. At this point the jaws automatically open, well clear of the welding area, and the nut is clamped to the panel by the electrode. The forging pressure and welding current are then applied for the preset time.



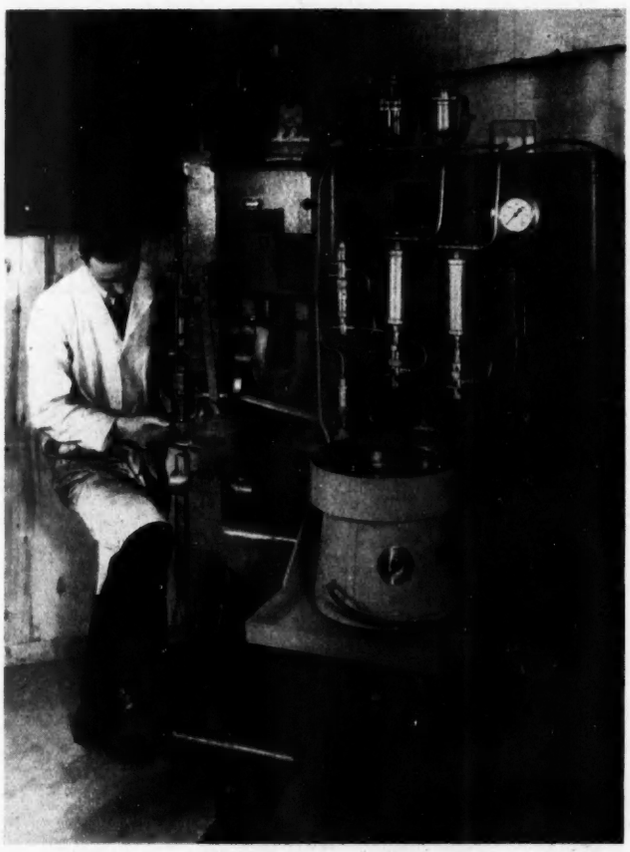
Nut gripping attachment on upper electrode. The nuts are delivered to the jaws by compressed air through the flexible plastics tube at the rear

At the end of the welding period the top electrode slide is retracted and the jaws automatically close ready to receive the next nut when the electrode comes to rest in its top position.

The bowl feeder orientates the nuts in the correct welding position and delivers them in a row to an attachment in the form of a breech block. When the electrode slide reaches its top position in the sequence of operations an air cylinder in the breech block transfers one nut to the entrance of the feed tube, whence compressed air delivers the single nut through the tube into the jaws of the electrode assembly shown in our second illustration. The jaws are pivoted on a block fixed to the electrode holder and are held in the closed, or nut receiving, position by two spring-loaded bars. At their upper ends these bars pass freely through holes in a bracket on the fixed head of the machine.

In the welding cycle as the electrode descends, with the electrode pushing the nut and jaws in front of it, the bars slide through the holes in the head bracket until stop nuts come into effect to arrest their further downward movement. At this point the nut in the jaws is just above the panel and registering on the lower locating pin. Continuation of the downward movement of the electrode holder causes the arrested bars to pull the jaws apart and release the nut, which is pushed on to the panel and welded.

It will be seen from the illustration that the new feeding equipment does not in any way reduce the capacity of the machine or obstruct the operator's view of the work during welding. The operator using both hands has full control of the panel at all times and his work is now reduced to simply positioning the holes in the panel on the location pin in the required sequence and depressing the pedal to start the automatic welding cycle.



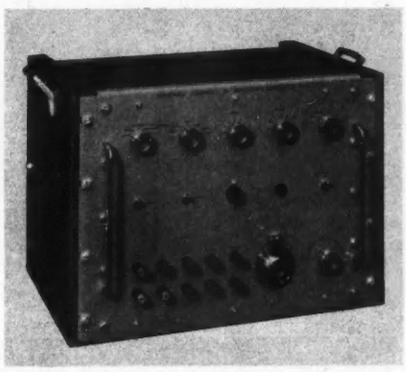
Welding machine fitted with automatic nut feeding equipment which in each cycle delivers a nut into jaws on the upper electrode assembly

Low-Frequency Waveform Generator

We illustrate an "LF.51" low-frequency waveform generator, made by Servomex Controls, Ltd., Crowborough Hill, Jarvis Brook, Sussex. It is designed to generate a great variety of electrical test signals over the range of frequencies used in servomechanisms and process controllers and it has useful fields of application in programming automatic systems, in analogue computation and in physiology.

It can generate sine waves from 500 c/s down to 0·0005 c/s, which is equivalent to one cycle every thirty-three minutes; it can generate square waves and pulses with durations from 100 microseconds up to 1000 seconds with a rise time, from 10 per cent to 90 per cent, of 5 microseconds; and it can generate ramp functions and triangular, sawtooth, trapezoidal or cosine-shaped pulses. Besides continuous operation it has facilities for one-half cycle or one complete cycle.

The "LF.51" generator incorporates an integrating amplifier which converts steps of input voltage into ramps of output voltage. A single linear transition from one to the other provides the normal ramp. Two such transitions, with no time delay, form a triangular pulse which, by the introduction of a delay, can be transformed into a trapezoidal pulse. The steps of input voltage are obtained from a trigger circuit which can be switched manually or by an external electric drive, or by the integrator itself, in which case the operation becomes self-sustaining and results in the output of square waves of



The low-frequency waveform generator shown here generates a variety of test signals from 500 c/s down to one cycle in thirty-three minutes, with facilities for generating one cycle or half-cycle, as well as continuous operation

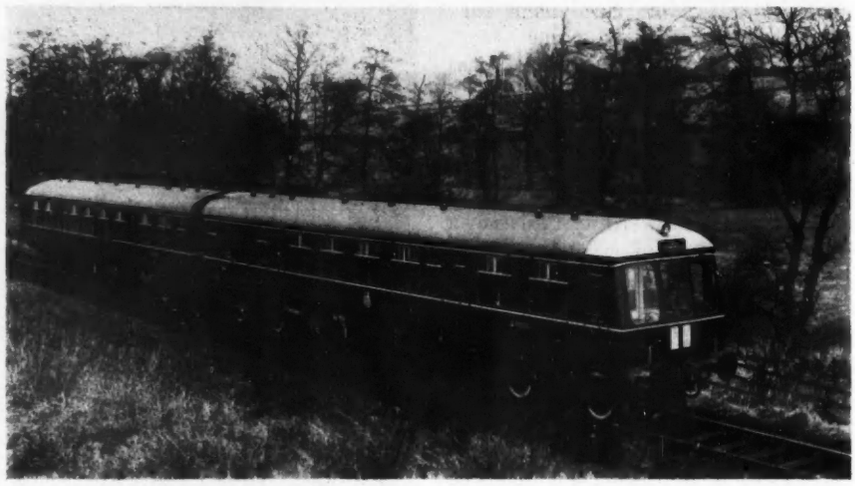
voltage from the trigger and triangular waves from the integrator.

By having different integrating rates in the two directions, unsymmetrical waves can be generated. The circuit controlling the output trigger pulse is arranged so that the sweep of the detecting oscilloscope starts before the main signal; accordingly, the whole transient response can be observed without any delay line. The integrating amplifier is of the kind used in analogue computers; there is no steady voltage across the integrating capacitor, so that leakage of this component is relatively unimportant.

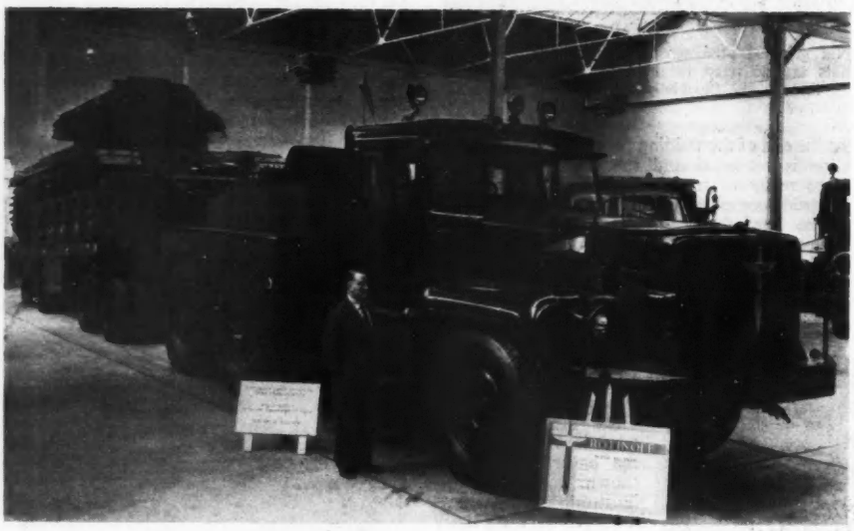
Sine waves are generated from the triangular waves by using a non-linear resistor, made up of a chain of biased diodes. The output approximates to a sine wave by a series of straight line segments. The accuracy of this method could, in theory, be made very high by using enough diodes, but in practice the accuracy is set by the stability of the components. In the "LF.51"

Applications of Oil Engines

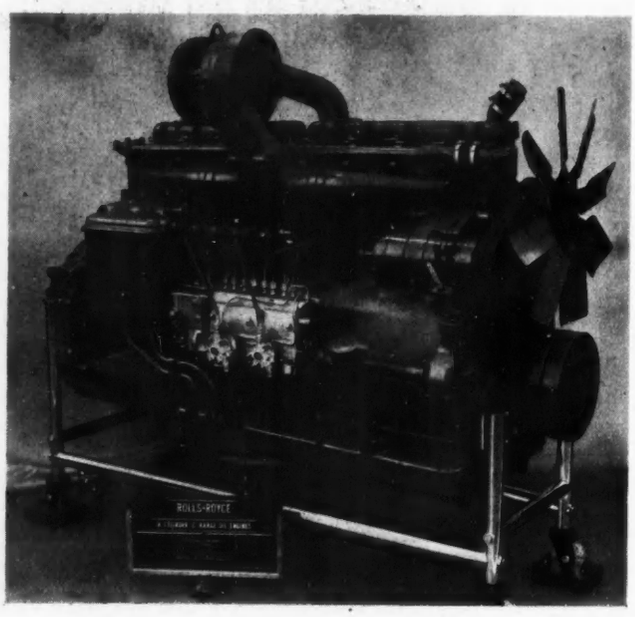
The uppermost picture shows the first of a number of railcar sets to be built for British Railways: each has a motor-coach with two 238 h.p., eight-cylinder motors driving the inner axles through torque converters providing direct drive and hydraulic braking. The straight eight has been accommodated also in the Rotinoff "Super Atlantic" seen in the next picture: in supercharged form it provides 335 b.h.p. at 2100 r.p.m. Transmission is by six-speed synchromesh and three-speed auxiliary boxes, each with overdrive ratios, and a third differential to the single wheels of centre and rear axles. Gross train weights of 200 tons can be handled by this tractor, and high convoy speeds maintained with such a load as the tank transporter shown.



Bottom, left, is an E.R.F. articulated quarry wagon, the tractor being powered by the 200 h.p. six, coupled to a torque converter. The three-speed gearbox is mounted far back, controlled by two push-pull linkages, and has indirect ratios of 0·67 and 1·8; these give, respectively, a maximum speed over 35 m.p.h. and 2·8 m.p.h. on a well-surfaced 1 in 5·7 gradient at a gross weight of 50 tons. The final reduction is by planetary trains in the hubs.



Bottom, right, is an AiResearch "T-14" turbo-charger on the eight-cylinder engine. This runs up to 50,000 r.p.m., 45,000 continuous maximum, on plain bearings fed with filtered oil from the engine lubricating system. The impeller is fully shrouded, cast in one piece in aluminium alloy by an investment process, and dynamic balance is attained by removing metal both from the rear face and from the shroud. The turbine wheel is austenitic and accepts temperatures up to 760 deg. Fah.; the example here has a forged radial section and cast whirl section, but one-piece cast wheels are envisaged. Balance of the rotating assembly is critical, c.g. position being held within 0·0002in, and split bearings in a built-up carrier are used to avoid dismantling the rotors after balancing. The "T-10" on the six-cylinder engine runs at 60,000 r.p.m., or 65,000 maximum; both give a charge density ratio of about two at higher mass flows. The engine seen here is governed at 1800 r.p.m. in turbo-blown form; the six gains 50 per cent in torque at 2100 r.p.m.



generator the biasing network is made up from specially manufactured wire-wound resistors, so that it can be guaranteed that the approximate sine wave does not deviate from the theoretical voltage by more than 1 per cent of the amplitude. The total distortion is less than 1 per cent, under these conditions. The amplitude of the generated waves is 75V peak, and this large amplitude is helpful in removing errors due to variations between diodes, &c. The amplitude of the signal is the same for all waveforms and for all frequencies. One consequence of the method of generating the sine waves is that changes of frequency take place immediately ; there is no " settling time " while the transients die away.

The " LF.51 " generator contains thirty-five valves (mainly from services approved list) and, to give accessibility, these valves and the associated components are mounted in six plug-in units, any one of which can be operated at the end of a short cable with terminating connectors. To facilitate cooling, the whole assembly is made from aluminium alloy. The instrument is designed to withstand shocks up to 40*g* in any direction. It weighs 66 lb and the overall dimensions are 19in by 14in by 16¾in.

Applications of Oil Engines

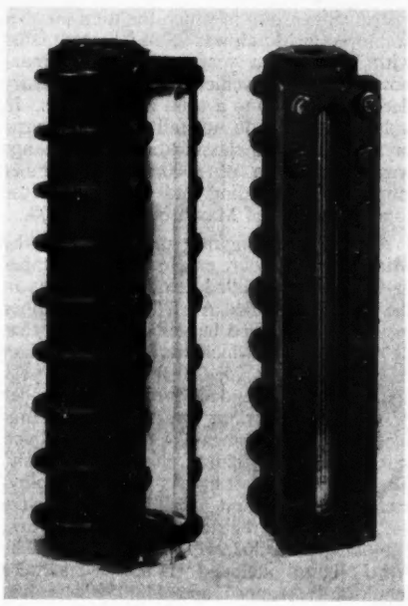
THE oil engine division of Rolls-Royce, Ltd., held last week an " At Home " at Derby. In the five years that have elapsed since the first engine was sold, the four-, six-, and eight-cylinder normally aspirated and supercharged engines have been applied to a diversity of machines and used in many extremes of climate. Installations that were on show included the first example of a railcar unit, ordered by British Railways, for the power units, transmissions and control gear of which Rolls-Royce have been responsible. The driven part of each twin-car set has two horizontal unsupercharged eight-cylinder engines driving through Twin Disc torque converters, built under licence at Crewe ; these include lock-up and hydraulic braking clutches (see page 249, March 9, 1956) and heat exchangers are provided to cool the fuel oil leaving the casings. Any oil passing the seals on the converter is collected and led to a sump with a readily visible level ; a leakage of the order of 1 pint a fortnight is tolerable. The final drive units, on the inner axles of each bogey, include dog-clutch reversing, the space needed for friction clutches being too great, at least in narrow-gauge vehicles. A set of tell-tales assures the driver that all the dog-clutches have engaged in the required direction ; interlocks are provided to prevent power being increased above idling until this is the case, or, if this is done, to prevent movement of the rack of the individual engine which is disengaged. At idling there is sufficient torque to move the train if the brakes are released, and thus to persuade the last clutches to engage. The control gear is built by Westinghouse to Rolls-Royce requirements, and uses pneumatic servo motors ; there are three rack positions, other than idling. Lock-up of the converters is automatic, to prevent the engines being stalled by drivers accustomed to fluid couplings ; lock-up occurs at two different speeds, depending on whether or not full power is selected, and in each case return to the converter mode takes place at a slightly lower speed. Thus, the driver's command is limited to selecting engine torque, direction of motion, and braking. In addition to the converters, pneumatic and vacuum brake systems are provided.

The three-stage converters were also in use on the Vickers " Vigor " supercharged, six-cylinder tractor, which dispenses with a change-speed gear and features a " hot shift " from forward to reverse by means of hydraulically operated clutches governing an epicyclic gear. This is built into the final drive and has two oil pumps on the outside of the casing, one for servo actuation and one for lubrication.

AiResearch blowers imported by Rotol, Ltd., were seen fitted to six-cylinder and eight-cylinder engines, raising the b.m.e.p. by as much as 50 per cent to as high as 118 lb per square inch ; outputs were, for the six, 300 h.p. at 2100 r.p.m. (200 h.p. at 2100 r.p.m. normally aspirated), and for the eight, 350 h.p. at 1800 r.p.m. (267 h.p. at 2100 r.p.m.). At present, these engines are only intended for " propeller law " applications, such as marine propulsion or drive through torque converters, but other uses are, of course, anticipated. In the experimental department there was seen a turbo-supercharger provided, in the the aircraft manner, with a by-pass gate, servo-operated, which was considered as a means of securing higher density ratios at low mass flows and using a smaller turbo-charger. In the case of an engine limited by peak cylinder pressures, this technique will allow an increase in maximum power ; it is superior to throttling the air intake in that the delay of the servo-mechanism favours rapid acceleration, allowing as it does overloading during the transient. This line of development ends, of course, in taking shaft power from the turbine.

Large Chamber Level Gauges

WITH a liquid, such as butane, which boils at atmospheric temperature, it is almost impossible to obtain an accurate reading of the surface level in an ordinary level gauge, owing to the surging that occurs. One way of overcoming this difficulty is provided by the Klinger-Hubbard level gauge which is artificially cooled by the expansion of gas in a separate chamber at the back of the gauge. However, a simpler method of overcoming this difficulty is provided by the Klinger " O " type large chamber level gauge shown in the illustration, which provides a greatly increased surface area for the liquid behind the sight glass. Should boiling or ebullition occur, the contrast between the liquid and the vapour space shown by the reflex glass is clearly visible without any surging. These gauges are also suitable for use with thick viscous fluids.



" O " type gauge shown with non-frosting attachment (left) and without non-frosting attachment (right)

The gauge body is machined from a 3in o.d. by 2in bore heavy gauge seamless steel tube with welded end plates which can be tapped for any required pipe connections. The borosilicate reflex gauge glasses are clamped in position by forged steel cover plates and specially shaped " U "-bolts. The gauges are capable of withstanding a hydraulic test pressure of 1800 lb per square inch and have a pressure rating of 600 lb, i.e. 820 lb per square inch at the maximum temperature of 660 deg. Fah., or 1200 lb per square inch at 100 deg. Fah. When the temperature of the contained fluid is below the freezing point of water the whole of the level gauge, including the glass window, is liable to be obscured by frost. In such cases a non-frosting extension of " Perspex " is fixed with a special optical cement to the front of the glass, as shown. Owing to its low heat conductivity, the " Perspex " acts as an effective insulator and no matter what thickness of frost builds up in the rest of the gauge, the internal liquid level can be read clearly through the " Perspex " and the reflex glass.

Double-plate or " Thru-Vision " level gauges (type " OT ") can also be supplied with a large chambered centre piece of similar dimensions. These gauges are fitted with flat plate glasses and cover plates on opposite sides of the 3in diameter centre column and provide a clear vision right through the gauge. Since the centre piece is slotted on both sides, the maximum test pressure is 900 lb per square inch and the pressure rating is 300 lb, i.e. 415 lb per square inch at the maximum temperature of 660 deg. Fah., and 600 lb per square inch at 100 deg. Fah.

Low Temperature Oxidation Plant

THE process of low temperature oxidation has been employed in numerous instances to render innocuous vapours of an objectionable nature. Catalytic combustion can successfully treat such mixtures as the effluents from phthalic anhydride plant and many other industrial processes, and is the preferred process where the mixture is substantially below the weak limit of flammability. Conventional combustion would then require the mixture to be raised to temperatures of the order of 1400 deg. Fah., whereas in the presence of a catalyst reaction may occur at about 500 deg. Fah. The heat rise in reaction is in many cases sufficient to raise the incoming gas to the required temperature in a heat exchanger ; if not, an electric heater or fuel burner is required, but frequently the reaction will liberate more than enough heat and allow an oven or boiler to be heated without the use of fuel.

Plant following these principles is now to be manufactured and marketed in the United Kingdom by W. C. Holmes and Co., Ltd., as the Holmes-Catco process. The catalyst is mounted on a frame and composed of nickel alloy ribbon with a platinum-group coating bonded to its surface. Element lives are one and a half to three years and elements can be reactivated. Apart from this, upkeep of the plant is confined to the induced draught fan or the heater if the application requires either or both. Installations in the United States have varied from 100 to 65,000 cubic feet per minute in throughput, and units have been supplied to Ford Motor Company for research on the treatment of diesel engine exhaust.

Winch for Scaffolding Cradles and Bosuns' Chairs

A WINCH for use with wire rope on applications such as controlling a bosun's chair or a cradle slung from the top of a building has been introduced from France by Tirfor, Ltd., 27, Broomgrove Road, Sheffield, 10. The winch is illustrated herewith. It is stated to carry a working load of 10 cwt with a factor of safety of twelve.

The winch is operated by turning a handle, which, through reduction gearing, turns two triple-grooved pulley drums. The rope is reeved three times round both pulleys, then a complete turn is taken round the upper pulley, then the rope passes round the lower pulley and out through a friction-tight grip between the lower pulley and the central spindle. The complete assembly has a pressed steel body and can be built into the framework of the lifting cradle to give the most convenient operation ; two or three winches can thus be incorporated in large cradles.

When lowering the cradle, a handle is lifted, thus disengaging a ratchet ; the winch handle must then be turned to lower the cradle. The rope is reeved to give a friction grip sufficient to hold the cable under load, and there are further safety devices such as a grip incorporated in the handle of the ratchet lever.

Industrial and Labour Notes

Engineering and Shipbuilding Wages

The executives of the forty unions affiliated to the Confederation of Shipbuilding and Engineering Unions met on Thursday of last week to consider the recommendations made in the reports of the Courts of Inquiry into the wage disputes. The foremost of those recommendations is that there should be negotiation on an unconditional wage increase of 8s. 6d. a week, or on an increase of 11s. a week with specified undertakings about restrictive practices and productivity.

The national committee of the Amalgamated Engineering Union passed a resolution in support of the 11s. a week increase, at the same time urging attempts to gain as much modification as possible of the conditions attaching thereto. At last week's meeting of the Confederation, however, the A.E.U. proposal failed to win the support of the majority. A resolution which was passed at the meeting authorised the Confederation to resume negotiations with the engineering and shipbuilding employers on the basis of the Court's recommendations.

Cost Stability

In his chairman's statement at the annual meeting of the Bristol Aeroplane Company, Ltd., on Tuesday, Sir Reginald Verdon Smith commented on this country's "continuing failure to achieve reasonable stability in costs." It was worrying to industry, he said, because inflation was outside the control of any single industrial undertaking, especially one concerned with an end-product, and in recent months it seemed once again to have proved to be beyond the control even of a Government which had the intention of curbing it.

It was worrying, too, Sir Reginald continued, because it was so closely linked with the stability of labour relations. In so many other aspects of industrial relations, wise and progressive policies were being jointly pursued with much success, but when the question of wage rates was mentioned, Sir Reginald commented, wisdom and progress gave way to pressure for annual increases irrespective of productive efficiency or the effect upon the real value of money. These wage demands, Sir Reginald added, had now become a "chronic disease of the economy," and no remedy had yet been found which the patient was willing to accept and adopt. Yet, he said, it was no longer possible to treat such demands with sympathy as though they were the result of price increases, when it was openly acknowledged that claims were put forward in anticipation of price increases to be expected later on.

Sir Reginald went on to stress that overseas buyers, upon whom all depended for their standard of living, were only interested in quality, price and delivery dates, and not in the domestic problems of the British economy. Whilst a national wages policy might be disagreeable and difficult, the present display of unenlightened sectional self-interest was foolish and shortsighted and totally removed from the objectives of thrift, saving and increased productive investment which the country so urgently needed. It was greatly to be hoped, Sir Reginald concluded, that fresh efforts could now be made to develop and adopt new methods and procedures, both nationally and within the engineering industry itself, for the settlement of wage differences. But, he urged, however excellent the procedure, it would be the attitude of mind and the sense of responsibility displayed by all concerned which would decide whether we could as a nation grasp the opportunity of industrial progress which scientific developments had made possible, and which in a competitive world we could not afford to lose.

Employment and Unemployment

There was a drop of about 40,000 during March in the number of people in civil employment in Great Britain. The total at the end of the month was 22,908,000 (15,200,000 men and 7,708,000 women).

Of the total, 3,963,000 people were engaged in the country's basic industries during March, there being increases, mainly seasonal, in the manpower of agriculture and transport. In the manufacturing industries the employment total declined by 46,000 to 9,143,000. The biggest decrease, of 14,000, occurred in the engineering, metal goods and precision instruments group in which the total number employed in March was 2,784,000, compared with 2,817,000 a year earlier. The manpower of the vehicle building industry declined by 2000 to a total of 1,190,000. In industries which do not fall within the basic or manufacturing classifications, one change was an addition of 8000 to the number employed in building and contracting, the total at the end of March being 1,502,000.

According to figures published by the Ministry of Labour, employment exchanges in Great Britain filled 169,066 vacancies in the five weeks ended April 10. The number of vacancies notified but still unfilled on that date was 285,000, which was 34,000 more than on March 6, but 106,000 fewer than a year ago. In the week ended March 30 the number of operatives working short time in manufacturing establishments was 82,000, which was 27,000 less than a month previously. The Ministry's latest figures about unemployment show that on April 15 there were 342,259 people registered as out of work, compared with 362,945 on March 11. The April figure included 21,009 who were temporarily stopped and 158,051 who had been unemployed for more than eight weeks.

Temporary Transfer of Workers

The Minister of Labour, Mr. Iain Macleod, has announced details of a new scheme to assist the temporary transfer of workers from areas where there is a redundancy of labour which is not expected to be permanent. This scheme, which will operate from June 11, applies to workers who have been unemployed for at least eight weeks, for whom there is no immediate prospect of obtaining employment locally, and who continue to maintain dependants at home.

The scheme provides that such workers must take up employment, beyond daily travelling distance, for which no suitable local unemployed worker is available, and this must be done with the prior knowledge of the Ministry of Labour's local office. A lodging allowance will be paid at the rate of 35s. a week and will continue for up to twelve months, so long as no suitable employment is available in the home area. Other assistance includes fares to the new area and fares to the home area to be interviewed for employment or to take up employment.

Mission to Canadian Oilfields

At a reception held last week, prior to the departure of the British engineering mission to Canadian oilfields and refineries, which is sponsored by the Council of British Manufacturers of Petroleum Equipment, Mr. J. M. Storey, the leader, stated that the growth of the oil equipment industry in Britain had kept pace with the expansion of the oil industry and that now all refinery equipment could be supplied. The object of the mission is to inquire into the conditions in Canada and to inform the rapidly developing Canadian oil industry of the scope of the equipment manufactured in this country.

Mr. Storey said that the members of the mission would assemble in Montreal on May 25 and travel from east to west, calling at Ottawa, Toronto, Sarnia, Winnipeg, Regina, Calgary, Edmonton, and Vancouver. Mr. T. M. Burns, of the Office of the High Commissioner for Canada, extended good wishes to the mission and mentioned that, at present, most Canadian requirements came from the U.S.A. He expressed his conviction that the visit of the mission would result in greater awareness in Canada of the potential of the petroleum equipment industry in the United Kingdom and that its report would undoubtedly encourage British firms to enter the Canadian market.

Iron and Steel

Although the engineering strike continued to affect steel production during the early days of April, production for the month averaged 430,000 tons a week. That represented an annual output rate of 22,360,000 tons, compared with a rate of 21,896,000 tons in April last year. Pig iron production in April averaged 277,400 tons a week, and was a little higher than in any month previously.

The Iron and Steel Board has stated that total deliveries of steel, including exports by producers, averaged 321,800 tons a week in the first quarter of this year, and were 2·3 per cent higher than in the corresponding quarter of 1956. But the Board points out that, within the first quarter's total, export deliveries were 20 per cent higher and deliveries to home consumers were 0·7 per cent lower than a year ago. Home users also purchased substantially less imported steel. In total, home users received from United Kingdom and imported sources 278,400 tons a week in the first quarter of this year, which was 6·4 per cent less than in the comparable quarter of 1956.

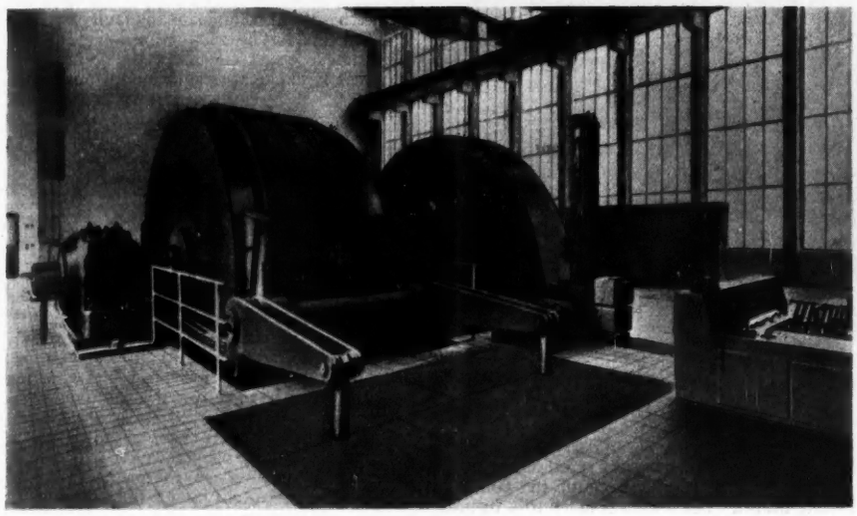
The Iron and Steel Board has announced increases in the maximum prices of a limited range of steel products. They include non-alloy steel wire rods, rivet bolt and nut bars, cold-rolled strip, intermediate widths of hot-rolled strip and bright non-alloy steel bars. The maximum prices of individual items in this range of products have been increased by amounts varying from 10s. to £3 a ton. The new prices took effect on May 13.

German Industries Fair, Hanover

No. III—(*Continued from page 735, May 10*)

GUTEHOFFNUNGSHUTTE STERKRADE A.G.

SOME important achievements of this company could only be shown in the form of models. We illustrate a d.c., four-rope friction winder for a German coal mine, designed for a payload of 25 metric tons and, as such, stated to be one of the largest winding engines in the world.



25-ton winding gear—Gutehoffnungshutte Sterkrade

The machine floor of the winding tower is some 57m above ground level and provides room for another similar machine, which will be installed later. The hoist is equipped with six-deck cages, each deck accommodating a tub holding 4150 kg. With a maximum depth of 1200m, the rope tension at the hoist is about 110 tons. Rope speed is 16m per second. The friction pulley has a diameter of 5·4m and is fitted with four 51mm diameter ropes.

MASCHINENFABRIK ESSLINGEN

Our illustration shows the model " DES 15 " mandrel lift truck of Maschinenfabrik Esslingen, Esslingen/Neckar, which was shown for the first time equipped with diesel-electric drive. The vehicle is capable of handling 15-ton loads and possesses a diesel-driven generator set of 38kW capacity. The same engine drives also high pressure oil pumps for the lifting cylinder and the power assisted steering. The two main motors are d.c. and differentially arranged. Two forward and two reverse speeds can be switched in, the fine adjustment being obtained by varying the speed of the diesel engine by a pedal lever. Hydraulic brakes are provided for the front gearing and for the rear wheels ; there is also a mechanical parking brake. There are eight solid-tyred wheels in front and four similar wheels at the rear. The truck can turn within a circle of 9m diameter ; it has an empty weight of about 20·5 tons. Maximum speed with load is 10km per hour, maximum gradient 2·5 per cent when empty and 1·0 per cent laden. The mandrel lifts between 600 and 2600mm.

15-ton mandrel lift truck—Maschinenfabrik Esslingen

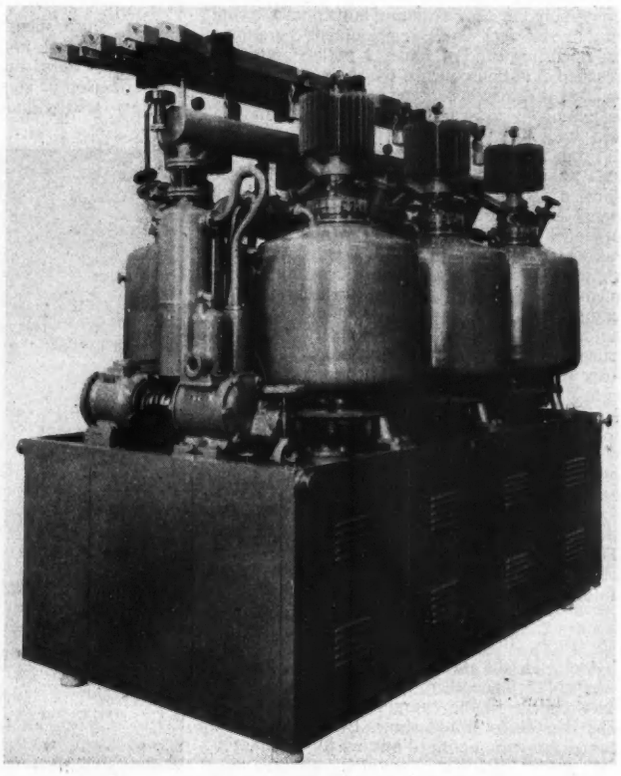
BROWN, BOVERI ET CIE.

In the field of mercury vapour rectifiers, Brown, Boveri et Cie., Mannheim, showed a new standard range of air-cooled, steel-enclosed, mercury arc rectifiers, designed for operation up to 750V and currents of 375A, 750A and 1500A. The design has been applied to rectifier-controlled mine hoists, for which purpose a number of single rectifiers are used in parallel. By contrast with the larger water-cooled rectifiers used hitherto, these are stated to be more economical, since a smaller number of standby units has to be kept in operation.

The use of improved operated control gear in industry is increasing, particularly in rolling mills. Its response is but little affected by the motor vapour, which is frequently present, and the sensitivity is so great that the instruments can be mounted at sufficient distance from the heated metal surfaces.

At this year's German Industries Fair, Brown Boveri showed for the first time its improved control gear, which is stated to respond only to changes in radiation, so that slow disturbances (changes of the daylight, warming up of roller beds, &c.) do not interfere with correct functioning, and a zero adjustment is not required.

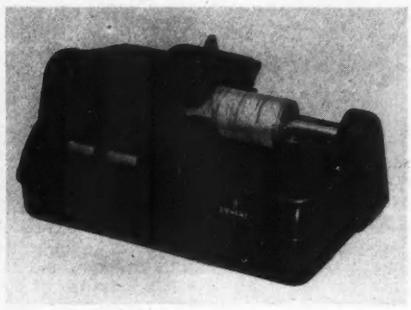
An arithmetical unit for multiplication and division, which does not contain any mechanical components, was also shown. The instrument makes use of magnetic amplifiers ; the input being two sinusoidal or fully rectified alternating voltages, the output being proportional to their product. More complex calculations can be carried out by using several units in combination. The equipment is used in rolling mills.



Block of six single anode water cooled rectifiers for converting 3kV, 45 c/s, three-phase current to 2·5kA, 680V, d.c.—Brown, Boveri

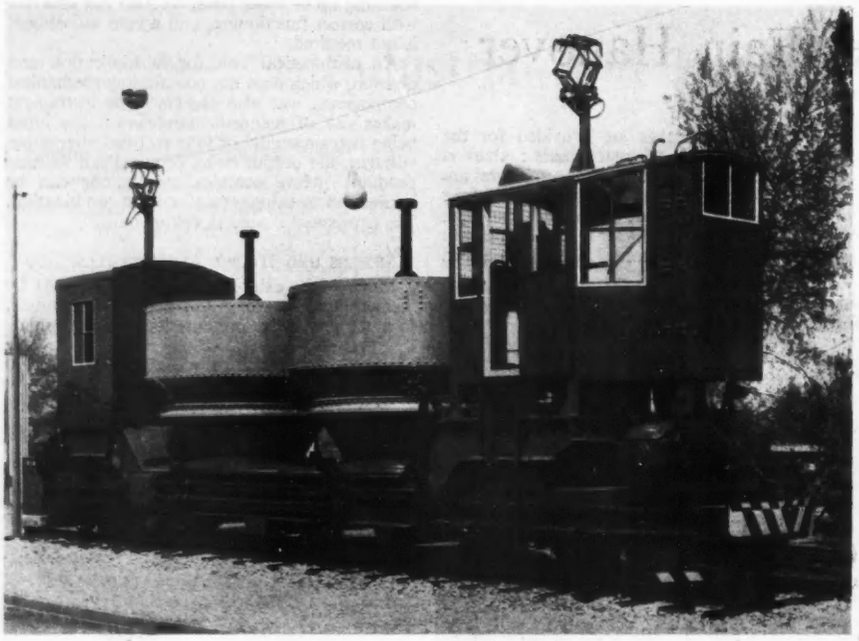
SIEMENS UND HALSKE AKTIENGESELLSCHAFT

Much of its exhibition space was devoted by Siemens und Halske A.G., Berlin and Munich, to a comprehensive presentation of its telephone equipment. Among the new developments in this field was the " Silafon," which comprises a microphone and loudspeaker as well as a hand instrument with amplification.



Facsimile telewriter for use over normal telephone lines—Siemens

Facsimile reproduction of text, sketches, and signatures, over ordinary post office telephone lines is made possible by a novel instrument, the " Siemens-Hell-Fax KF108 " which uses a carrier frequency of 2400 c/s. The original is scanned by means of lamp and photocell at the rate of 1000 prints per square centimetre. The receiver uses a small inked marking wheel to print on ordinary unpre-



Feeder car for blast-furnace charging—J. Pohlig A.G.

pared paper. All reproduction is in black and white, without semitones. Synchronism is ensured by operating both the sender and the receiver from the a.c. grid, by means of synchronous motors. Largest useful paper area is 190mm by 138mm, which is transmitted in about 3½ minutes, smaller areas taking proportionately less time. This is stated to correspond to a transmission rate of 850 letters per minute (if special small type is used for the original), while the speed of a teleprinter is 400 letters per minute.

For telephone installations with two to ten lines and 10 to 100 extensions, Siemens und Halske has introduced a quick-action relay with palladium contacts, a number of which are used in place of the traditional rotary selectors. By combining the relay armature and contact spring into one element which weighs only 0·3 gramme, an operating time of under 2 milliseconds was reached ; in consequence the making of a connection is nearly instantaneous. The installation is practically noiseless and is stated to have a very long life.

From an extensive production programme of railway signalling equipment Siemens und Halske showed a signal-box with diagrammatic control panel and automatic block control, operating a model railway track, and showing the overtaking of a goods train on a gradient by an express. Train-operated level crossing equipment was shown in the open air section. This comprised intermittent warning lights and fully automatic half-gates. The gates serve chiefly to safeguard against the possibility of cars crossing after the passage of a train while a second train is due. Since only the approach half of the road is closed by the gate, it is not possible for vehicles to be trapped between descending gates.

Perforated tape equipment for use in conjunction with typewriters or accounting machines has been developed by Siemens and was shown for the first time on the stands of Olympiawerke and Zeiss-Ikon Büromaschinen G.m.b.H. The perforated tape contains all the information on the typed original, and can be used for the automatic production of punched cards.

J. Pohlig Aktiengesellschaft

Alongside the stand of J. Pohlig Aktiengesellschaft of Cologne, there was shown an interesting development in the charging of blast-furnaces. The illustration above shows two large circular containers with a conical bottom for discharging the cokes or ore mounted on a deep railway wagon, which is electrically propelled. Each container holds 12 cubic metres, or about 5·25 tons of coke, or 13 tons of mixed iron ore. The driving motors and the speed reducing gears are mounted on the bogies. Provision is made for rotating the containers at a speed of 11 r.p.m., so as to ensure good mixing of the contents during transit. The wagon is taken to a vertical lift which raises the container to the blast-furnace charging platform.

(To be continued)

Television Equipment for Testing Welded Pipes

Testing of welded products by means of X-rays at the Thyssen Works of Phœnix Rheinrohr A.G., at Mülheim (Ruhr), dates back to 1934, when a 200kV installation was put into service. Since then, the equipment has been greatly expanded, until at the present time there are six 300kV and one 400kV sets. In addition, a 1 curie isotope source of Cs 137 is used, and ancillary testing methods include the use of ultrasonics, especially for sheet. In spite of this, part of the output of mechanically welded pipes could be subjected to spot tests only, although 6000 to 8000 film exposures were taken each month. In order to rationalise the test procedure it was decided to substitute the direct viewing of the X-ray pictures on a fluorescent screen. By employing an image intensifier and thus increasing the amount of light by a factor of 1000, it became possible to examine wall thicknesses of up to 20mm in a continuous manner. About 14km of welds are at present being tested in a month ; the method has the further advantage over X-ray photography that the result of the test is immediately available so that steps can at once be taken to eliminate any faulty welds.

The method has been in use for a year and has, it is stated, been fully successful. The only drawback is the great strain which is put on the examiner, which easily leads to fatigue and, hence, to mistakes. It was decided to seek a way in which several operators could carry out the inspection jointly, so that the responsibility would be shared and the strain on each would be reduced. In co-operation with the firms C. H. F. Müller and Deutsche Fernseh G.m.b.H., a television installation was developed which allows this to be done (see illustration). The equipment, which is stated to have been used at the Thyssen works for the first time in Europe, employs a television camera to observe the picture produced by the image converter. This picture has already undergone a one-thousandfold intensification ; further amplification takes place in the television circuit. Trials have shown that welding faults can be interpreted from the television picture as well as from an X-ray photograph. Besides giving a continuous picture which is accessible to a number of observers, the method is stated to have the great advantage that positive or negative screen images can readily be obtained.

The Euratom Report

Last November the Foreign Ministers of the six E.C.S.C. countries—which now form Euratom—requested a survey concerning the amount of atomic energy required by the Coal and Steel Community in the next few years, and the probable cost of providing it. They charged Monsieur Louis Armand, Herr Franz Etzel and Professor Francesco Giordani with the task of preparing a report, which was published on May 7. The report recommends that the six countries build nuclear power stations with a total generating capacity of 15,000MW, able to produce 100,000 million kWh a year, by the end of 1967. Although this target is

The X-ray image of the pipe weld is intensified a thousandfold by an image converter and is then viewed by the television camera. The television screen can be viewed by several observers

ambitious—present plans of the Community countries together would complete only 6000MW by 1967—it is well within the six countries' industrial capacity. While their target of 15,000MW is two-and-a-half times Britain's aim of 6000MW by 1967, the population of the Community is three times as large as Britain's and its electricity output 2·8 times greater. Moreover, the six countries' need is greater, since they are already importing nearly one-quarter of their rapidly-increasing energy needs, while Britain imports only 12 per cent.

The report states that the installation of 15,000MW will permit the Community countries to stabilise their energy imports by 1963 at a level of around 165 million tons of coal equivalent (3300 million dollars at present price levels) per year, and thus reduce their present precarious reliance on Middle East oil. Without nuclear power, energy imports would rise from 2000 million dollars a year at present to 4000 million dollars in 1967, and might reach 6000 million dollars by 1975.

These energy imports, although measured in terms of coal equivalent, consist mainly of oil, the bulk of which could only come from the Middle East. Thus, without nuclear power, Europe's dependence on the Middle East is bound to increase.

To begin quickly, the report states, the Euratom countries must either buy some reactors from the United States and the United Kingdom or build them under licence. The only full-scale designs immediately available are the American pressurised-water/boiling-water reactor (PWR/BWR) and the British gas-cooled PIPPA reactor of the Calder Hall type.

The report contains the first thorough comparison of the cost of electricity produced by British and American nuclear reactors. The detailed study of costs in Annex II shows clearly that, while the initial investment cost is rather higher for the British stations than for the American stations, and the fuel costs considerably lower, the costs per kilowatt-hour of electricity produced are remarkably similar over a fifteen-year amortisation period, ranging from 0·011 to 0·014 dollar per kilowatt-hour. This is hardly higher than the cost of electricity produced in new conventional power stations using imported fuel, placed at 0·011–0·012 dollar per kilowatt-hour. The report stresses that production costs in nuclear power stations are likely to fall appreciably over the next ten to fifteen years, while the cost of conventional energy will rise. At the same time, there is little danger of the first nuclear power stations becoming obsolete, as their very low operating costs will still make them economical through most of their useful life.

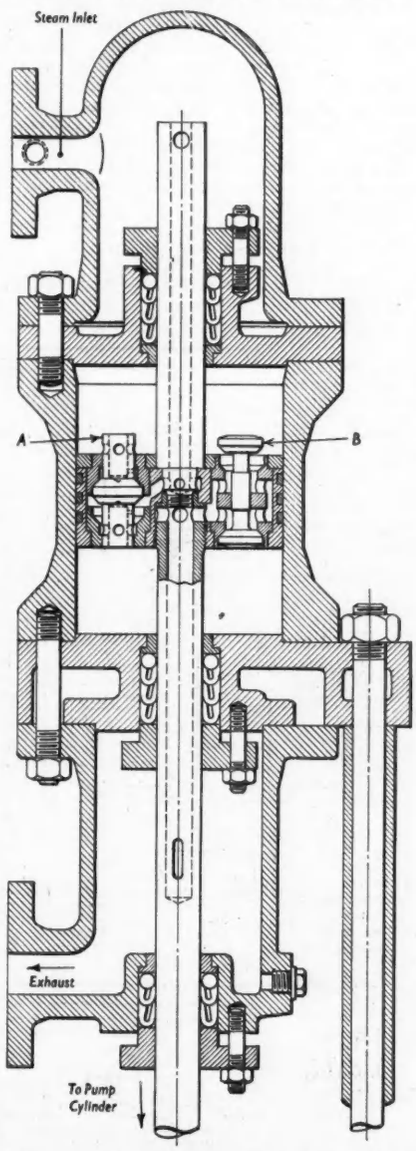
Both the United States and Britain have promised co-operation with Euratom by supplying technicians and training facilities, and the United States and Canada have given assurances that supplies of nuclear fuel will be readily available to Euratom, the report states. With the United States, a " two-way traffic " is foreseen, with Europe supplying " practical knowledge gained by the large-scale industrial application of nuclear power," in exchange for the full technical information of fissile materials offered by the American authorities. Britain, for her part, has declared herself willing " to facilitate contacts between British firms and those in Europe interested in building the Calder Hall type of reactor."

While fuel costs of nuclear power stations are a fraction of those in conventional stations, the initial investment is much greater. The outlay required by the 15,000MW target is 6000 million dollars, compared with 2000 million dollars for conventional stations of the same total capacity. " This additional investment burden creates some difficult problems for our national economies," the report states. The report recommends that the Euratom Commission and the governments and industries concerned should immediately study ways of providing the necessary additional investment funds. As far as the balance of payments is concerned, big foreign currency savings are envisaged after the first years, through the saving on coal and oil imports, despite a moderate increase in initial requirements of foreign currency to pay for nuclear plant and fuel.

Boiler Feed Pump

A novel design of boiler feed pump is the " Perkeo " pump, which is manufactured by Ruhrpumpen, G.m.b.H., Witten-Annen, Stockumer Strasse 10, West Germany. The construction of the steam cylinder is shown in the accompanying illustration. It will be seen that steam is admitted through the top part of the hollow piston-rod to the slide valve *A*, which is situated in the piston itself. The piston also contains the exhaust valve *B*, through which exhaust steam passes to the bottom portion of the bore of the piston-rod and hence to the exhaust space. In the position shown live steam is being admitted to the bottom cylinder space, while the top space is exhausting. When valve *A* hits the top cylinder cover it is pushed downwards relative to the piston, and thus the steam is reversed. At the same time the exhaust valve *B* is closed to the top space and opened to the bottom space. The design thus avoids the need for a separate slide valve and valve gear. It will be seen that when the steam is turned on the slide valves move into their top or bottom end positions owing to the differential steam pressure. Similarly, when the ends of the valves touch the top or bottom covers the reversal is completed by the difference in pressure on the two sides of the piston.

Besides its simplicity, the pump is claimed to have a low steam consumption, owing to the small amount of dead spaces. The valve arrangement can withstand high pressures and is not sensitive to the presence of condensate ; in fact, the pump can be operated with high-pressure water. It is stated that the speed can be reduced down to about 3 cycles per minute, merely by adjusting the inlet valve. The pump will begin to operate at pressures as low as 1½ atmospheres gauge, and is designed for delivery pressures of up to 40 atmospheres. The range in sizes varies from 90mm bore and 100mm stroke (pump cylinder bore 60mm) to 310mm bore and 170mm stroke (pump cylinder bore 210mm).



Valve-gear-less boiler feed pump. The steam cylinder only is shown

German Nuclear Power

A few weeks ago it was announced that Rheinisch-Westfälische Elektrizitätswerke A.G. had placed a contract for the first atomic power plant to be built in Germany. The station, which is to come into operation by the end of 1959, will be built by Mitchell Engineering, Ltd., London, and its American associate, A.M.F. Atomics Incorporated, New York, The British contribution will be the reactor shell, heat exchangers, and other equipment concerned with the purely atomic side of the plant, while the American firm will furnish the reactor core and the control devices. The supply of other plant and the civil engineering work will be carried out by German enterprises.

Designed for an electrical output of 15MW, the plant will have a closed-cycle boiling water reactor supplying steam at 530 deg. Fah. and 900 lb per square inch to the primary circuit, from which heat is transferred to generate secondary steam for the turbines at 600 lb per square inch and 489 deg. Fah.

It is now announced that A.V.R. e.V., Düsseldorf, has placed a contract with Brown Boveri A.G., Mannheim, and Friedrich Krupp, Essen, for the design of another nuclear power plant, also of 15MW electrical output.

A.V.R. (Arbeitsgemeinschaft Deutscher Energieversorgungsunternehmen zur Vorbereitung der Errichtung eines Leistungsversuchsreaktors) is a study group comprising the electricity supply undertakings of Bremen, Duisburg, Düsseldorf, Hagen, Hameln, Hanover, Herford, Kiel, and Wuppertal.

The reactor is to be a new design, of the homogeneous gas-cooled and graphite moderated type, and will use fuel elements made of sintered uranium carbide and graphite. The fuel elements are loaded from the top and removed from the bottom of the reactor vessel. Control will be carried out by varying the uranium charge and the amount of coolant, no shim and control rods being employed. It is hoped to achieve a high rate of burn-up by resintering the elements at intervals, thus healing the damaged structure. This concept is stated to allow considerably higher operating temperatures than any existing reactor ; it is intended to generate steam at 980 deg. Fah. It is believed that power costs will compare favourably with those of a conventional coal-fired plant. No location has yet been selected. It is hoped to have a pilot plant ready in 1960.

As announced by the German Minister for Atomic Energy, Dr. Siegfried Balke, the generation from German atomic power stations is to reach 1,500,000kWh by 1965, or three times the amount previously envisaged. The cost of the new plan, which is to be submitted to the Bundestag shortly, is said to amount to DM.2500 million.

Instruments and Automation Congress

During the period November 2 to 10, the " Interkama, 1957 " congress and exhibition will be held in Düsseldorf. (The initials stand for Internationaler Kongress mit Ausstellung für Messtechnik und Automatik—International Congress and Exhibition of Measuring Instruments and Automation). This is the first independent event of its kind to take place in Germany, and it is hoped to bring together users and manufacturers of measuring instruments and control devices. Special provision will be made at the Interkama for maintenance courses, which will be held during the whole of the exhibition. Full information may be obtained from the organiser, Nowea Nordwestdeutsche Ausstellungsgesellschaft m.b.H., Düsseldorf, Ehrenhof 4, German Federal Republic.

Eddystone Steam Power Station

BY OUR AMERICAN EDITOR

No. II—(*Concluded from page* 739, *May* 10)

The 325MW super-pressure unit which is to go into operation at the Eddystone power station of the Philadelphia Electric Company in 1960 *is to-day the most advanced steam-electric generating scheme under construction in the United States. It is hoped that the unit will achieve a net heat rate of* 8016 *B.Th.U. per kilowatt-hour and a* 42·6 *per cent thermal efficiency. The boiler has been designed to deliver steam at a pressure of* 5000 *lb per square inch gauge, at a temperature of* 1200 *deg. Fah. and at a rate of* 2,000,000 *lb per hour. The turbine will have eight rotating elements on two shafts, rotating respectively at* 3600 *r.p.m. and* 1800 *r.p.m.*

Turbine Design

THE Eddystone turbine plant is rated at 325MW and is designed for inlet steam conditions of 5015 lb per square inch absolute at 1200 deg. Fah., with two stages of reheat to 1050 deg. Fah. It will exhaust at 1 in Hg absolute. Initially, nine stages of extraction feed heat were contemplated and corresponding extraction connections are provided in the turbine design. However, only eight extraction stages are actually used, since a stack gas cooler has been interposed. The system will heat the feed water regeneratively to 551 deg. Fah. at rated output, this temperature increasing to about 563 deg. Fah. at the discharge of the high-pressure boiler feed pump. In Fig. 6 we show the Eddystone station heat balance for the maximum steam flow of 2,000,000 lb per hour at the turbine stop valves. Steam pressures and temperatures are shown for the various extraction points, i.e. cardinal pressure points, and their location relative to the individual elements of the turbine is indicated. This illustration shows all the components of the turbine cycle normally in use. The main flow of steam from the turbine stop valves is, in series, through the super-pressure (s.p.) and the very-high-pressure (v.h.p.) elements, the first reheat stage, the high-pressure (h.p.) turbine stages, the second reheat stage, and finally through the intermediate (i.p.) and low-pressure (l.p.) turbines to the condenser.

Among the numerous problems imposed by the design premises, one has to do with the rather small volumetric steam flow at the turbine inlet stage, and another is concerned with the relatively very large flow volume at the exhaust blade. In spite of the fact that 39 per cent of the admitted steam is extracted at intermediate points for feed heating, the ratio of the terminal volumetric flows is two-thousandfold. Of course, there was no question but that the higher pressure elements should operate at 3600 r.p.m. However, there was some question with regard to the optimum speed of the low-pressure turbine. An 1800 r.p.m., double-flow low-pressure element was chosen to reduce the exhaust-leaving losses to a minimum and to obtain an optimum overall station heat rate. The unit is therefore of the cross-compound design with 3600 r.p.m. and 1800 r.p.m. sections. As indicated in Fig. 6, in the 3600 r.p.m. section the right-hand element is the s.p. turbine, and the second component in tandem is the v.h.p.-h.p. turbine, combining, in one casing, the v.h.p. and the h.p. stages for series steam flow. The 1800 r.p.m. section consists of the i.p. turbine to the right, coupled to the l.p. elements in tandem. At rating, the high-speed section develops 45 per cent of the combined unit output. In the following description of detailed turbine design, particular attention will be devoted to the 3600 r.p.m. elements, which involve most of the unusual design aspects.

Super-Pressure Element

Alternative constructions were studied for that portion of the turbine expanding steam from inlet pressure to the first reheat point, or to approximately 25 per cent of initial steam pressure. The conclusion was to split this expansion between two elements for the purpose of securing the smallest practical element which would then be subjected to steam pressure or temperature beyond the limit of present operating experience. In Fig. 7 we show a longitudinal section of the 3600 r.p.m. unit, with the s.p. turbine at the right. Steam at 5015 lb per square inch absolute and 1200 deg. Fah. is supplied through four inlet lines, each having its own stop and governing valve. Each of these inlets is connected to one of the four nozzle chambers which provide full circumferential admission to the first of a total of five impulse stages. The first stage only is velocity compounded. This stage is used to extract the maximum possible energy, thereby effecting a maximum reduction in steam temperature. In spite of this reduction, the temperature encountered at the exit of the first stage is approximately 1120 deg. Fah. at maximum steam flow. From the final s.p. turbine stage, steam exhausts at 2500 lb per square inch absolute, at which point the temperature is 1000 deg. Fah. The first stage of this turbine element is designed for operation with complete admission at all loads. Partial-load operation with sectional valve control was considered, but it was found that the partial admission forces resulted in an excessive deflection of the relatively light rotor, and the blade shock loading was high enough to be of some concern. As a result, all governor valves will operate in unison.

It will be noted from Fig. 7, that the shape of the outer casing of the s.p. element approaches that of a sphere. It is a casting of ferritic steel (2¼ per cent Cr, 1 per cent Mo, ¼ per cent V), horizontally split and flanged, and is supported at the centre line on the adjacent pedestals. It, in turn, provides centre line support and key guidance for an inner casing of cast A.I.S.I. type-316 austenitic steel (17 per cent Cr., 12 per cent Ni, 2½ per cent Mo), which contains the working steam until its pressure has been lowered to 2500 lb per square inch. The inner casing is also horizontally split and flanged, and supports the inter-stage diaphragms and the four 90 deg. cast A.I.S.I. type-316 austenitic steel nozzle chambers through welded connections at their steam inlet necks. Two steam inlets are provided in both the inner and outer casing, covers and bases. These pipes, which also are of austenitic type-316 alloy, are connected to the outer casing through transition pieces and welds. Prolongations of the inlet pipes extend into the nozzle chambers through slip joints, which are sealed by stacked sealing rings. This construction provides rings which are alternately fitted with very small clearance to the turn of the inlet pipe and the bore of the nozzle chamber. Thus, relative motion of the component parts is provided in all directions.

These pipe extensions are for some distance parallel and in close proximity to the outer casing, the transition piece and its welds. To shield the latter from the 1200 deg. Fah. inlet piping radiation, particularly in the zone where dissimilar metals are joined by welding, baffles are placed between the inner pipe and the outer casing snout. They consist essentially of spirally surfaced cylinders surrounding the pipes, supplemented by orificed steam leak-offs from the casing end of the transition pieces and terminating in the v.h.p. turbine. Consequently s.p. turbine exhaust steam at 1000 deg. Fah. flows outward and then inward along the cylindrical baffle to the v.h.p. unit, with an insignificant overall loss in thermal availability while still providing adequate cooling. Furthermore, to ensure that radiation from the inlet portions of the inner casing will not cause excessive heating of stagnant steam and too high a temperature in the ferritic outer casing in this vicinity, an auxiliary exhaust pipe has been provided on both the outer casing cover and base at this end of the

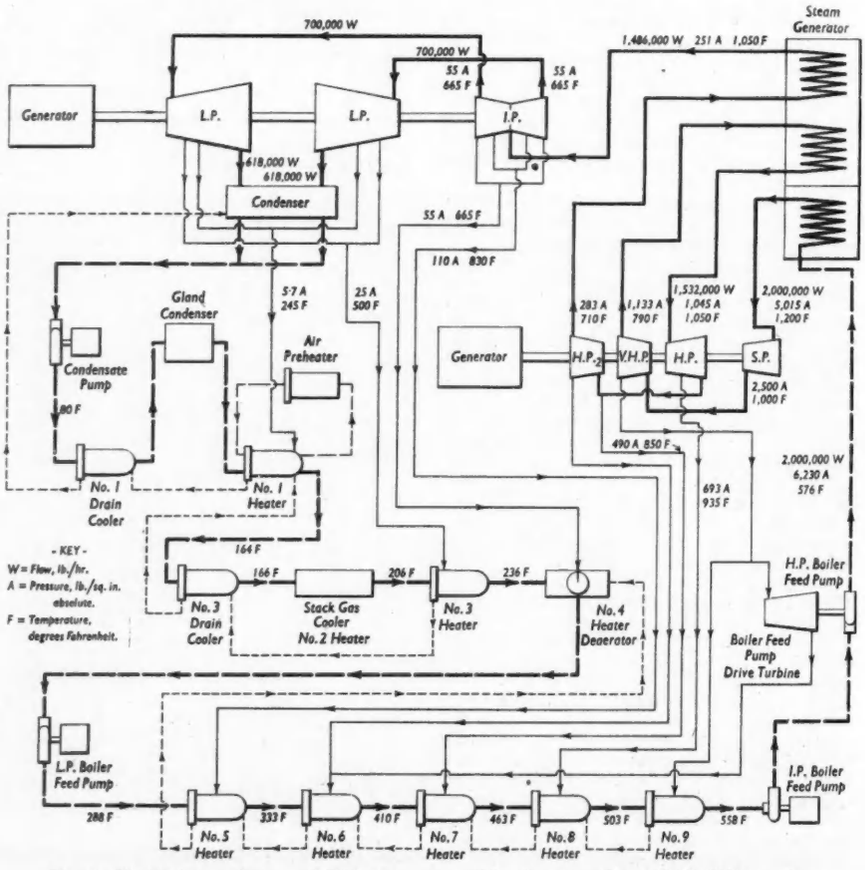


Fig. 6—Heat balance diagram of Eddystone power station for steam flow of 2,000,000 lb per hour

s.p. turbine element. These pipes connect back into the main exhaust pipes from the s.p. turbine element. Thus the entire outer casing is bathed internally by exhaust steam.

A consideration of the probably relatively large differential expansion of rotors and casings due to the high operating temperature, together with the necessity of accurate control of leakage passages because of the dense operating medium, indicated the desirability of providing individual longitudinal positioning bearings for each of the 3600 r.p.m. rotors. The s.p. and v.h.p.-h.p. rotors are therefore connected through a longitudinally elastic coupling, and each rotor has its own thrust bearing of Kingsbury design. Also, because of the high steam pressure and density involved the problem of sealing the steam at the casing ends becomes very important. If sufficient conventional radial step-type labyrinth seals were applied to keep the leakage within reasonable limits, they would require an extremely long turbine rotor. Such a long rotor presents difficult forging and thermal expansion problems. These problems are being reduced by the application of a nested radial seal. By this means a satisfactory number of individual throttlings can be obtained within reasonable axial spacing. This construction is used in the seal between the first stage and the outlet of the forward end of the inner casing, and again at both ends of the s.p. element from the exhaust pressure to the leak-off of the steam seal outer glands. These glands comprise a series of alternately stacked complete ring stationary and rotating members, each of which carries a number of ribbon seal strips on its interspaced lands. Siemens-Schuckert in Germany, with whom Westinghouse has reciprocal technical relations, has used this construction successfully for some time at comparable leakage steam temperatures.

No extended practical experience is available about high-speed rotors subjected to within 140 deg. Fah. of the first stage operating temperature expected at Eddystone. This is perhaps the most important consideration which led to splitting off the s.p. element into one of small overall dimensions. The situation can be appreciated from a consideration that the s.p. rotor will weigh only about 3500 lb, while this element will produce 44MW output. As a result, particularly of its small diameter rotor, the operating stress levels will be quite conservative for some of the well-known high-temperature alloy forgings. However, although the rotor has been reduced to a small component, for single-piece construction, it requires an ingot and rough forging which is well beyond prior experience in the production of these high-temperature alloys.

At present it has not been decided definitely which of several alternate s.p. rotor alloys or constructions will first be proved adequate and accepted for use. Westinghouse "Discaloy" material has been used extensively for gas turbine and jet engine disc forgings of the diameter required here, but without the thickness or body length and without integral shaft ends. However, the Bethlehem Steel Company has worked diligently on the matter and has produced single-piece "Discaloy" forgings of suitable dimensions which are under metallurgical processing and examination. Concurrently, William Jessop and Sons, of Sheffield, undertook to supply a single-piece forging of "G18B." Here also the forging is large compared with those that have been produced to date of this popular gas turbine alloy. The first Jessop forging for this job was lost, but a second one is well along in manufacture. Either of the foregoing alloys would be expected to provide a normal long-life rotor. To assure that an operable rotor will be available, single-piece forgings have been ordered of a 12 per cent chromium, A.I.S.I. type-422 alloy and a chromium-molybdenum-vanadium forging commonly used in steam turbine rotors. This chromium-molybdenum-vanadium forging will be produced by the "vacuum-poured" method. These are being provided purely as insurance against any possible delay resulting from an unexpectedly long period of development being required for the "Discaloy" or "G18B" forgings. Present knowledge indicates that these back-up rotors would have a reasonable but limited service life under full temperature operation. It is the expectation of Westinghouse that several of the foregoing rotor material and design programmes will be brought to a satisfactory conclusion. In addition, it is hoped that service experience will be obtained on the more promising of the alternate rotors.

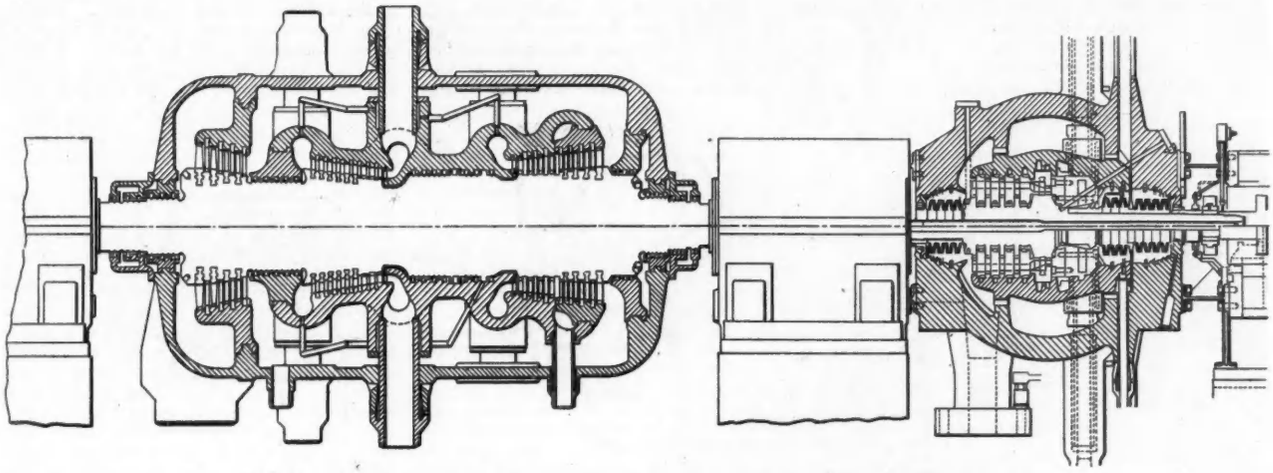


Fig. 7—Longitudinal section of 3600 r.p.m. turbine unit, with super-critical pressure turbine at right

Steam is supplied to the s.p. turbine through four main leads of 5in i.d. by 10$\frac{5}{16}$in o.d. Each lead is field-welded to a special connector just ahead of the stop valves, which reduces the inlets to 4$\frac{1}{4}$in i.d. by 9$\frac{3}{4}$in o.d. Each inlet is provided with a stop valve and a governing valve, which are closely coupled. Each set of stop and governing valves is supported within a steel framework or "sled," which in turn is fixed rigidly to the turbine foundation. Initial adjustment of the "sled" position is made with spacer blocks to provide for "cold spring," so that at full load the leads connecting to the turbine are theoretically free of bending stress.

Regarding the alloy selection for s.p. turbine construction, type-316 stainless steel has been used for all components in contact with substantially initial steam temperature or pressure. It is worth noting, however, that new metallurgical specifications have been prepared for this basic alloy, whereby all components are subjected to searching inspection before application. In addition to the normal chemical and physical property tests, determinations will be made of hot ductility, creep rupture values and grain size, and soundness will be determined by dye penetrant and ultrasonic testing.

Very-High-Pressure–High-Pressure Component

The next main turbine component in series is that designated as v.h.p.-h.p. in Fig. 6. This unit houses two complete and independent elements. At maximum flow, the s.p. exhaust into the v.h.p. element is at about 2500 lb per square inch absolute and 1000 deg. Fah. In turn, the v.h.p. stages exhaust to the first reheater at 1133 lb per square inch absolute and 790 deg. Fah. Incidentally, this is also the point at which steam is extracted to supply the ninth or top regenerative feed water heater and also the turbine which drives the high-pressure boiler feed pump. Steam returning from the first reheater at 8 per cent reduced pressure, but at 1050 deg. Fah., then expands through the h.p. turbine stages to the second reheater system, at a maximum flow pressure of 283 lb per square inch absolute. As indicated in Fig. 6, the v.h.p. element is situated in the centre of the turbine : steam flow is away from the s.p. unit and its thrust is completely balanced by a labyrinth piston. This casing is constructed of 2$\frac{1}{4}$ per cent Cr, 1 per cent Mo, $\frac{1}{4}$ per cent V ferritic steel, and, in addition to housing the v.h.p. element, it also includes the first portion of the h.p. element. The h.p. element is split to provide opposed direction series flow through the turbine stages situated at each end of the combined unit. One purpose of splitting the h.p. flow path is to obtain self-balancing as far as thrust is concerned ; furthermore, it provides steam flow at intermediate pressure and temperature between the inner and outer casings to absorb any inlet packing leakage and perform a mass flow cooling function for the outer casing, which is constructed of 1 per cent Cr, $\frac{1}{2}$ per cent Mo material.

One of the critical aspects of design of the h.p. element is the rotor carrying the blades which take the reheated steam. Blade loading, accompanied by the high-temperature level, has been given careful consideration with regard to the rotor material for satisfactory operation under such conditions. It is interesting to note that the blade fastenings for the first four rotating rows are of the side entry design, which eliminates, to the greatest extent, load concentrations at any particular point on the rotor. The maximum steam temperature at the exit of these four stages is 935 deg. Fah., at which point standard blade grooves are entirely adequate.

Immediate Pressure Element

Steam from the second reheater returns to the i.p. turbine, which, in connection with the l.p. turbine, comprises the 1800 r.p.m. shaft. A longitudinal section through the i.p. and l.p. turbine elements, is shown in Fig. 8. In the i.p. element, the double flow design principle is used with steam admission at the centre of the casing. This construction results in the most advantageous arrangement from considerations of the rotor forging and of the casing structure. The rotor is of the built-up design with the centre core of the rotor forging of a material suitable for operation at the elevated temperature encountered. The double flow design permits the use of a relatively small diameter rotor lending itself to a practical forging of the chromium-molybdenum-vanadium material required. While

the stresses in this rotor are within conservative limits, rotor cooling in this critical area is applied. Steam for the No. 5 heater is taken from a zone in the i.p. turbine element where the stage pressure is 110 lb per square inch absolute and the temperature 830 deg. Fah. This particular zone is at the end of the group of blading carried by the solid core of the turbine rotor forging. Since the temperature at this zone is reduced to a value which permits the use of drum discs, the remainder of the blading is carried by two discs of nickel-chromium-molybdenum material, shrunk and keyed on to both ends of the centre core shaft. This construction permits a turbine rotor of high-temperature alloy material to carry the blading in the high-temperature region, and, at the same time, permits the installation of the longer exhaust pressure stages on separate discs of high-tensile strength.

The construction of the i.p. turbine element provides separate nozzle chambers to prevent the 1050 deg. Fah. steam from contacting the turbine outer casing. These nozzle chambers are constructed of 2¼ per cent Cr, 1 per cent Mo, ¼ per cent V material. Provisions have been made for cooling the i.p. spindle in the vicinity of steam admission. Steam from the exhaust of the h.p. turbine element at a temperature of 710 deg. Fah. is brought through the i.p. turbine inner casing and nozzle chambers and admitted so that it can flow through the space beneath the nozzle chamber and outwardly to the working parts of the turbine. The design also provides for mass flow cooling of the inner casing which is of 2¼ per cent Cr, 1 per cent Mo, ¼ per cent V material. This is done by placing a single extraction opening for the fifth heater at one end of the pressure zone terminating with the i.p. turbine inner casing.

Steam from the i.p. turbine element is exhausted through four 34in diameter openings, two of which are situated at the governor end of the i.p. turbine and two at its generator end. This particular zone, which is at a pressure of 55 lb per square inch absolute and a temperature of 665 deg. Fah., provides the steam for the fourth heater, which is of the deaerating type. Steam is extracted from both ends of the i.p. turbine exhaust through an equaliser pipe, so as to balance the flow and pressure at this zone.

Low-Pressure Element

The l.p. element has been designed to obtain high capability and good vacuum conditions which require that large exhaust annuli be provided to reduce the leaving losses to a minimum. The large physical size of the last row of blades, if applied in the conventional double-exhaust arrangement, would result in a composite l.p. turbine rotor which would be either beyond or tax the capacity of conventional crane handling equipment, both at the manufacturing works and in the power station. In addition, the physical size and great weight would make handling during shipment a difficult problem. To reduce this weight, the l.p. turbine element is divided into two separate individual sections. The general arrangement of the l.p. element and its physical relation to the i.p. element is shown in Fig. 8. This general arrangement of the l.p. turbine elements resulted from a study which indicated that almost intractable problems associated with foundation and condenser design would become inevitable with any other previously used turbine arrangements. The separated sections are placed with exhaust ends adjoining in order that the steam may flow into a condenser with a single inlet opening. This arrangement would present a very difficult design problem relative to the length of the longitudinal supporting members of the foundation, if it were not for the transverse beam section of the foundation which has been provided under the common pedestal between the two l.p. ends. This arrangement, together with the natural requirements of the condenser, form a reasonable solution to the problem which exists. The condenser is arranged with two tube bundles, and the centre steam lane between the bundles ensures satisfactory steam distribution throughout the condenser tubes. This arrangement permits the use of two water boxes external to the condenser shell, and in the resultant space between the water boxes, a vertical column may be placed. These vertical columns, one on either side of the turbine, support the transverse member under the turbine and by this support the span of the longitudinal beams is reduced to practical limits.

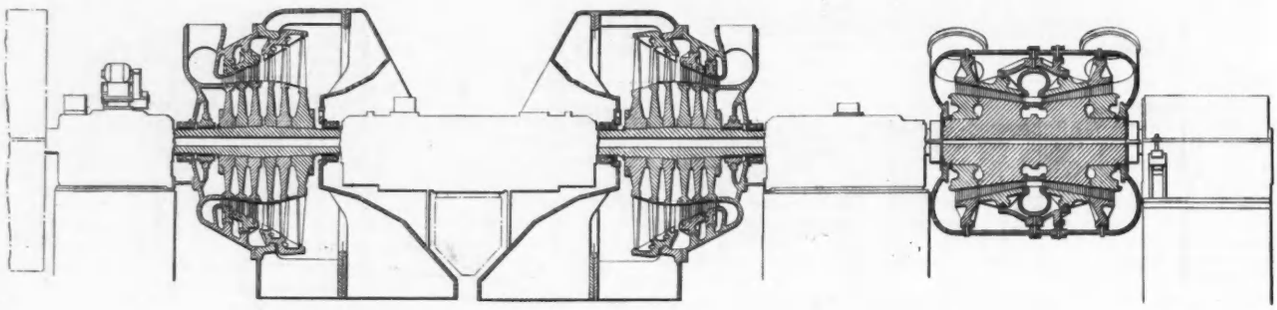


Fig. 8—Longitudinal section of 1800 r.p.m. turbine unit with intermediate pressure turbine at right

Steam from the exhaust of the i.p. turbine enters the l.p. elements through connections which are situated in the cylinder covers. The l.p. elements are provided with two extraction points for feed water heating. The first point, which is at a pressure of 25 lb per square inch absolute and a temperature of 500 deg. Fah., provides steam for the No. 3 heater. It should be noted that the No. 2 heater does not receive extraction steam from the turbine but is fed by a stack gas heat exchanger. Provision is made, however, for a connection to the No. 2 heater extraction zone. The lowest pressure extraction zone provides steam at 5·7 lb per square inch absolute at a temperature of 245 deg. Fah. A part of this steam is utilised in the No. 1 heater. In addition, steam from this zone is utilised for air preheating purposes. The rotors are built up from profiled discs and drum discs which are shrunk and keyed to the centre core shaft. The transverse beam between the two l.p. turbine exhausts provides a substantial support for the bearings of the two rotors. The connecting shaft between the two l.p. rotors is provided with a means for balancing.

During the preliminary considerations for this unit, it was planned to utilise water-sealed glands at all low-temperature gland seals. Further considerations of the starting cycle requirements and the exacting requirements for feed water purity led to a review of the original approach. It was ultimately decided to extend the conventional practice of employing steam-sealed glands at all high-temperature gland seals to include all glands on the unit. As is Westinghouse practice, when exhaust end glands operating at low temperature are included in the gland steam seal system, a supply steam desuperheater is installed. A gland steam condenser and steam seal regulator is provided to maintain the proper pressure balance of the system.

Condenser Design

Since the exhaust of the Eddystone unit will contain only about 4000 B.Th.U. per net kWh generated, the condenser is probably one of the smallest on the basis of square feet of area per kW of capacity. It is, nevertheless, a very large condenser, containing 150,000 square feet, which is made up of 25,730 tubes 30ft long and ¾in diameter in a single-pass arrangement. Two circulating pumps will deliver water from the Delaware River at the rate of 200,000 gallons per minute. The water boxes will be divided and will be fabricated of steel plate. The tubes will be of uninhibited "Admiralty A" alloy, which has given most satisfactory performance heretofore in Delaware River water. The tube sheets will be of Muntz metal. The condenser will be solidly supported with a rubber expansion joint at the turbine exhaust connection. The two circulating-water pumps turn at 250 r.p.m. and are each driven by a 900 h.p. motor. They are vertical mixed-flow pumps of 72in diameter. The circulating pump will be installed at the intake house some 1000ft from the condenser Trash racks, revolving screens and intermittent chlorination will be provided. The two precast concrete intake pipes are 78in in diameter.

Feed Water Heaters

With the exception of the deaerator, all of the feed water heaters are of the closed design. All high-pressure heaters have integral drain coolers, and those receiving high-temperature steam are provided with desuperheating zones to obtain the maximum rise of feed water temperature. The heater shells are flanged in such a way as to be removable without disconnecting any major water or steam line. The high-pressure heater channel covers are of quadrant design and of the pressure-sealed, man-hole form. There are two independent lines of heaters, each line being capable of carrying about two-thirds of the turbine full load. All heaters are arranged horizontally.

The design practice of the Philadelphia Electric Company in recent years has opposed the use of deaerators, it having been found by long experience that satisfactory deaeration could be obtained in the condenser. However, the urgency in this super-critical plant to obtain pure, oxygen-free water with an absolute minimum of chemical treatment dictated the use of a deaerator. It is installed at the bleed point of 55 lb per square inch absolute with an additional connection to the second cold reheat line to provide a floor of 3 lb per square inch gauge at flows below 30 per cent. Each deaerator is a single unit of the tray design. The feed water heater arrangement has already been shown schematically in Fig. 6. The first heater is of an unusual arrangement, containing two sets of tubes for reasons of plant efficiency to be discussed below.

Boiler Feed Pumps

The boiler feed pumps are arranged in a series of three—low, intermediate and high pressure. Each develops somewhat more than 2000 lb per square inch at full load. At shut-off and at loads up to about one-third of full load, the low and intermediate-pressure pumps operating without the high-pressure pump will develop more than 5500 lb per square inch. The low and intermediate-pressure pumps are driven at constant speed by two-pole induction motors, respectively sized 4000 h.p. and 4500 h.p. The

high-pressure pump is steam turbine driven, and therefore is capable of variable speed to satisfy the system requirements at above one-third rating. The feed pumps are in duplicate, each series of pumps being installed in one of the two lines of heaters as discussed previously. Thus a set of feed pumps and a line of feed water heaters comprise a unit, any component of which could cause the loss of half the feed water cycle. However, the remaining unit will be capable of carrying a feed water flow adequate for about two-thirds of plant capability. The sum of the horsepower required by the six pumps at full load on the main unit is about 23,000 h.p.

The low-pressure boiler feed pump is installed directly under the deaerator. It is a five-stage pump, employing double-suction, first-stage impellers. At full load the available suction pressure is 2250 lb per square inch. An interesting property of this pump is a small booster impeller mounted after the final main pump impeller. This is provided to supply a small additional head needed for satisfactory operation of the shaft seals, which are of the leak-off design, on this and succeeding higher pressure pumps. The intermediate-pressure pump is a four-stage pump receiving its suction from the low-pressure pump discharge by way of the high-pressure feed water heaters. Its suction pressure at full load will be about 2150 lb per square inch absolute and its discharge pressure about 4400 lb per square inch absolute.

The high-pressure pump, a cross section of which is shown in Fig. 9, is a six-stage pump receiving its suction directly from the intermediate-pressure pump and delivering feed water to the boiler at the required pressure. It is designed so that, at less than one-third plant load, the feed water may be pumped through it without danger to the pump or the pump drive. This pump is turbine driven, and the turbine receives steam from the first cold reheat and exhausts to the second cold reheat. Thus it is in parallel with the i.p. component of the main turbine and the pressure available for its operation is the pressure drop through this component of the main turbine. The condensate pumps are vertical tank pumps of four stages, which pump through the air ejector condenser

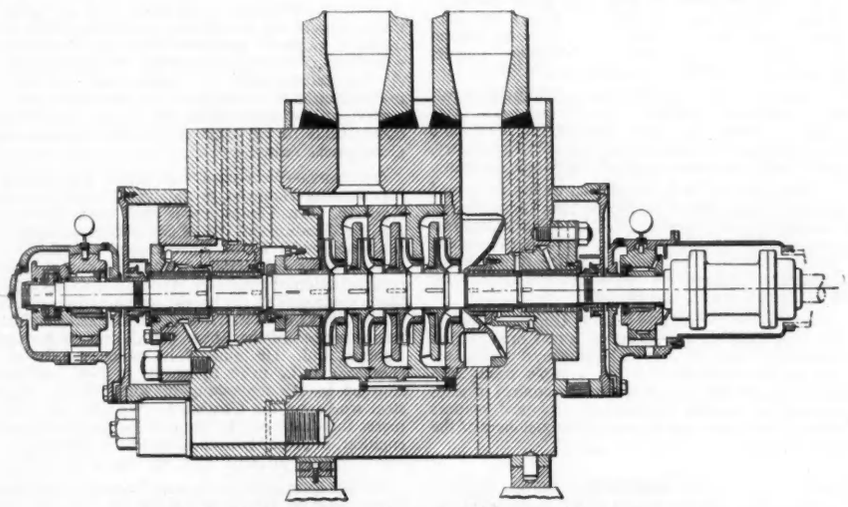


Fig. 9—Longitudinal section through high-pressure boiler feed pump

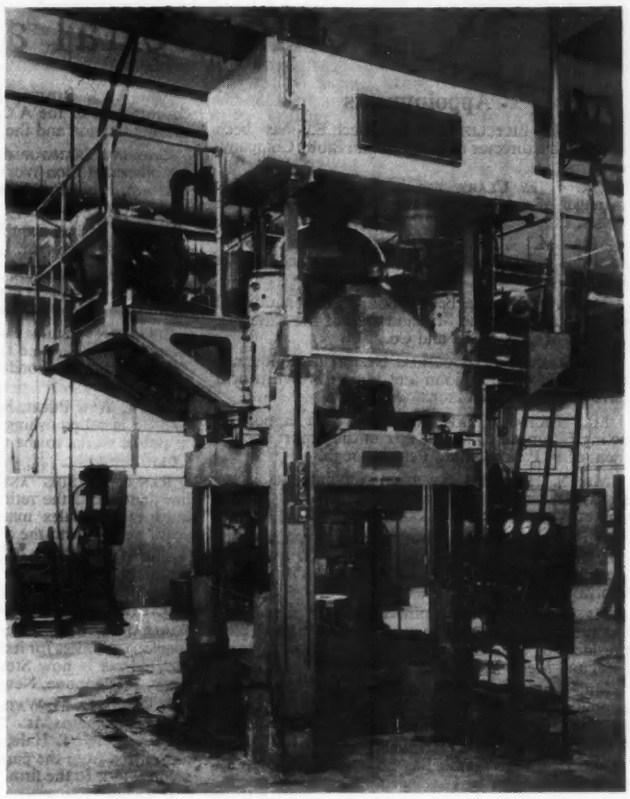
and the first three stages of feed water heating to the deaerator. The discharge pressure at full load is about 150 lb per square inch. Reciprocating dry vacuum pumps will be used for air removal from the condensers. These pumps will have a capacity of 8·05 cubic feet per minute of free air at 29in Hg. This pump has good characteristics with very high capacity at start-up conditions and, therefore, can evacuate the condenser very quickly.[4] On the other hand, it is capable of creating very high vacuum at the low flows normally associated with full-speed operation of the main unit.

Electrical System

The two generators of the cross-compound set will aggregate 416MVA and will generate at 20kV. They will be solidly connected electrically to each other and to two 200MVA step-up transformers with an output voltage of 132kV. The generators also will be connected to two auxiliary transformers rated at 12MVA each, at 4kV. The two main step-up transformers will be connected solidly on the 132kV side. Their output will be controlled by a single circuit breaker serving a single 132kV bus. The 132kV bus will supply three outgoing lines, a transfer bus to the future No. 2 unit and a 132/4kV starting transformer. This arrangement is simple and will provide ample means for transmitting the great output of this unit to the load. It also will make it possible to feed power into the station for starting purposes before the second unit is in operation and to transfer starting power from one unit to the other after the second unit is installed.

The auxiliary power system is basically a 4kV system. One half of the auxiliaries are connected to one auxiliary power transformer and the other half to the other auxiliary power transformer.

The starting transformer can provide emergency auxiliary power in the event of trouble on an auxiliary transformer. The load normally served by the auxiliary transformers is made up of the essential auxiliary systems, such as the circulating water pumps, the condensate and boiler feed pumps, the forced and induced draught fans, the coal pulverisers, the fuel oil pumps and the combustion control. In allocating specific motors between the two auxiliary transformers, great care has been exercised to keep sets of motors together. For example, all the motors in one line of feed water heaters are connected to one transformer, and half the fan motors or pulveriser motors serving each furnace of the boiler are connected to one transformer.



Hydraulic "Marform" press for the shaping of radioactive materials at Rocky Flats, Colorado

Hydraulic Press for Shaping Radioactive Materials

THE hydraulic press shown in the accompanying illustration is at present being installed at the Atomic Weapons works of the U.S. Atomic Energy Commission at Rocky Flats, Colorado, which is being operated by the Dow Chemical Company.

This machine, known as a "Marform" press, was developed and built by the Loewy-Hydropress Division of the Baldwin-Lima-Hamilton Corporation, of New York, and will be applied within a sealed chamber to the shaping of radioactive materials. The "Marform" press combines the Guerin rubber pad process with conventional, steel die forming. The male die is made of steel, but a rubber pad replaces the female die. As a result, die wear is substantially reduced, die replacement is needed less frequently and the surface shaped by the rubber mat retains its finish.

The process is economical in tooling cost and the rubber forming permits the deep drawing of thin materials without any wrinkling. The chamber in which the press will operate at the Colorado works will be an airtight structure of stainless steel and "Lucite," that will function as a shield against any contamination within the press. Long rubber gloves will be built into the shield to permit manual operations within the chamber.

Originally designed for the aircraft industry, "Marform" presses have been used for some years in this field to produce parts of higher quality than those available with other processes and to reduce die and finishing costs. The "Marform" process combines the economy of the rubber pad process with the accurate forming ability of the steel die. It is ideal for forming parts where surface finish and depth of draw are critical. The advantage of the "Marform" press is an ability to control the process so that a precise and stepless regulation of blank holding pressure may be maintained throughout the draw. The press permits the forming of tapered and other complex shapes in one operation.

Personal and Business

Appointments

MR. E. BILTCLIFFE, A.M.I.Mech.E., has been appointed a director of the Wellman Bibby Company, Ltd.

MR. J. E. CLARK has been appointed deputy manager of the Midlands district of British Oxygen Gases, Ltd.

MRS. M. WALKINS has been appointed Press relations officer of Rubery, Owen and Co., Ltd., in succession to Mrs. C. Clymer.

MR. F. BLINCOE has been appointed as an additional representative for the Midland area of the Salterpak division of Geo. Salter and Co., Ltd.

THE COUNCIL OF INDUSTRIAL DESIGN has announced that Mr. Howard Upjohn and Mr. Peter Whitworth have been appointed industrial officers.

MR. RICHARD TATCHNER has been appointed acting European zone manager in the export department of F. Perkins, Ltd., Peterborough.

MR. S. HARDMAN has been appointed assistant superintendent, switchgear department of Metropolitan-Vickers Electrical Company, Ltd.

THE NORTHERN ALUMINIUM COMPANY, Ltd., has announced the appointment of Mr. J. H. Mayes as general sales manager in succession to Mr. S. E. Clotworthy.

MR. FELIX L. LEVY, joint managing director of George Cohen, Sons and Co., Ltd., has been elected president of the National Federation of Scrap Iron, Steel and Metal Merchants.

MR. JAMES EADIE PETERS, M.I.E.E., has been appointed to succeed Mr. Hugh Glover Bell, M.I.E.E., as chief engineer to the North Western Electricity Board, with effect from September 1.

MR. D. C. ROGERSON has been appointed deputy publicity manager of The General Electric Company, Ltd., responsible for the company's publicity on heavy engineering and atomic energy.

THE LONDON TRANSPORT EXECUTIVE has announced the appointment of Mr. F. J. Lloyd as divisional superintendent, South West Division (Central Road Services), in succession to Mr. J. H. Giffin.

LLOYD'S REGISTER OF SHIPPING has announced that Mr. J. Hodgson, chief ship surveyor, is to retire on June 30, after nearly thirty-eight years' service with the Society. He will be succeeded by Mr. J. M. Murray.

THE CENTRAL ELECTRICITY AUTHORITY has announced the appointment of Mr. J. L. Ashworth, A.M.I.E.E., A.M.I.Mech.E., as deputy divisional controller of the North West, Merseyside and North Wales division.

THE BRITISH SHIPBUILDING RESEARCH ASSOCIATION has announced that its atomic energy studies are to form a separate section of its research studies and that Dr. J. E. Richards has been appointed head of the new section.

COLONEL ARTHUR C. R. WAITE has been elected president of the Bureau Permanent International des Constructeurs d'Automobiles for a period of two years. Dr. Biscaretti di Ruffia and Mr. M. R. Hohl have been elected vice-presidents.

MR. HARRISON LACKENBY, M.I.N.A., has been appointed naval architect to the British Shipbuilding Research Association, in succession to Dr. J. F. C. Conn, who is taking up an appointment as Professor of Naval Architecture at Glasgow University.

THE BRITISH TRANSPORT COMMISSION has announced the appointment of Mr. J. L. Willoughby as traffic manager, British Road Services (Parcels), Ltd. It has also announced that Mr. R. B. Hoff is to succeed Mr. A. Forbes Smith as chief stores officer at B.T.C. headquarters, when Mr. Smith retires at the end of May.

THE BRITISH ELECTRICAL DEVELOPMENT ASSOCIATION states that Viscount Chandos has been re-appointed president. Sir Josiah Eccles and Mr. Victor W. Dale have been appointed vice-presidents and Lord Beveridge and Captain J. M. Donaldson have been reappointed vice-presidents. Mr. W. S. Lewis has been elected chairman of the Council, 1957–58, and Mr. W. N. C. Clinch, M.I.E.E., vice-chairman.

Business Announcements

MR. J. M. ROBB, manager of the overseas division of Expandite, has left this country to visit France, Switzerland and Italy.

MR. I. E. GOOD, managing director of Keighley Grinders (Machine Tools), Ltd., is visiting the major industrial centres of Australia.

MR. A. J. ROMER, director of engineering and development of the A.C.V. Group of Companies, is touring Canada and the United States.

GRESHAM TRANSFORMERS, Ltd., states that it is now established at Lion Works, Hanworth Trading Estate, Feltham, Middlesex (telephone, Feltham 6661).

THE PULSOMETER ENGINEERING COMPANY, Ltd., states that it has acquired the whole of the issued share capital of Skyhi, Ltd., Isleworth, Middlesex.

A. KEMP AND SON, Ltd., Tenby Street North, Birmingham, 1, states that the whole of its issued share capital has been purchased by Barker and Allen, Ltd.

SIR OWEN WILLIAMS AND PARTNERS, 44, Park Road, London, N.W.1, state that they have moved to 101, Wigmore Street, London, W.1 (telephone, Hunter 9856).

MR. I. WYN PUGH, M.I.C.E., M.I.Mun.E., states that he is relinquishing his appointment as director of public works to the Government of Ghana (Gold Coast).

RANSOMES, SIMS AND JEFFERIES, Ltd., Ipswich, has announced the retirement of Mr. E. J. Bradley, lawn mower sales manager, after nearly fifty-one years' service with the company.

THE WHARTON CRANE AND HOIST COMPANY, Ltd., states that as from May 20 its London office will be situated at Lincoln House, 296–302, High Holborn, W.C.1 (telephone, Chancery 7911).

AERALITE, Ltd., states that it has acquired more spacious premises for its Newcastle upon Tyne depot; the address is now Stepney Bank, Newcastle upon Tyne, 1 (telephone, Newcastle 26805).

J. D. AND D. M. WATSON state that they have taken into partnership Mr. Terence Cripps, A.M.I.C.E., and Mr. Hugh T. Hale, M.I.C.E. Mr. P. G. Smales has retired from the partnership, but will continue as a consultant to the firm.

WORTHINGTON-SIMPSON, Ltd., Newark, Notts, states that it has concluded an agreement with the Worthington Corporation of Harrison, New Jersey, U.S.A., for the exchange of technical information for a further period of ten years.

THE SOLARTRON ELECTRONIC GROUP, Ltd., states that it has concluded an agreement with the Rheem Manufacturing Company, of New York, for the manufacture under licence in this country of the Rheem "F.151" gunnery trainer.

MR. E. S. WADDINGTON, manager of the industrial division of Philips Electrical, Ltd., has retired from the company's service. Mr. Waddington has started in practice as a consultant at 9, Thurleigh Avenue, London, S.W.12 (telephone, Battersea 7659).

COURTBURN POSITIONERS, Ltd., Kempston Hardwick, Bedford, states that it has formed a new associated company, Courtburn Supplies, Ltd., to handle the marketing of equipment for the welding industry, other than the manufactures of the parent company.

THE BOARD OF TRADE states that its insurance and companies department has moved from Lacon House, Theobalds Road, London, W.C.1, to Horse Guards' Avenue, Whitehall, London, S.W.1 (telephone, Trafalgar 8855). The bankruptcy department headquarters and companies inspection and liquidation branch remains at Lacon House.

THE AYLING INDUSTRIES GROUP, Horsham, Sussex, has announced the formation of a new organisation Ayling Nuclear Equipment Company, which, in addition to co-ordinating the group's production activities, will be responsible for the control of sales promotion and for advising on technical matters relating to nuclear products, to other members of the organisation.

Contracts

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, has received an order for two 150MW turbine-generator sets, complete with condensing, feed water heating and deaerating plant, from the Montreal Engineering Company, Ltd. The equipment covered by the contract, which is worth more than 5,500,000 dollars, is to be manufactured at the Metropolitan-Vickers works at Trafford Park, Manchester, and Germiston, Glasgow. It will be installed at the Wabamun power station of Calgary Power, Ltd. The new generating sets, which run at 3600 r.p.m., will have three-cylinder close-coupled tandem-compound turbines, each designed for a maximum economic rating of 120MW and a maximum capability rating of 150MW.

THE CENTRAL ELECTRICITY AUTHORITY has placed contracts during the past month for power stations amounting in the aggregate to £11,383,000. The principal contracts include: Belvedere power station, near Erith, foundations for turbo-alternator sets (John Mowlem and Co., Ltd.); Drakelow "B" power station, Burton-on-Trent, three 860,000 lb per hour boilers (Foster Wheeler, Ltd.), three cooling towers (The Davenport Engineering Company, Ltd.), and foundations for cooling towers, circulating water pump house foundations, ponds and culverts (Bierrum and Partners, Ltd.); High Marnham power station, near Tuxford, one 200MW reheat boiler (International Combustion, Ltd.), and second-half foundations (Taylor Woodrow Construction, Ltd.); and Skelton Grange power station, Leeds, foundations (J. L. Kier and Co., Ltd.).

Miscellanea

CONFERENCE ON EDUCATION FOR INDUSTRY.—The North Gloucestershire Industrial Education Council has announced its intention to hold a conference of industrialists and educationists, at Cheltenham, on October 9 and 10. The intention is to provide an opportunity for a full discussion of the promotion of education for industry, with special emphasis on engineering, as part of the school curriculum. Information concerning the programme of the conference can be obtained from the secretariat of the Council, 8, Lansdown Place, Cheltenham.

INSTITUTE OF SHEET METAL ENGINEERING.—At the annual general meeting of this Institute, the title was changed from Sheet and Strip Metal Users' Technical Association to the Institute of Sheet Metal Engineering. Mr. L. J. Tolley, director and general works manager of Renold Chains, Ltd., has retired from the office of chairman of the council and has been succeeded by Mr. R. Kirchener, M.I.Mech.E., M.I.Prod.E. Mr. Alastair McLeod, who has served the Institute as honorary secretary since its foundation in 1945, has resigned that office, and has been appointed honorary vice-president in recognition of his valued services. Mr. John Hooper has been appointed honorary secretary in his stead.

INTERNATIONAL GEOPHYSICAL YEAR.—An exhibition illustrating the scope and aims of the International Geophysical Year was opened at the Science Museum, South Kensington, on May 10, and will continue until October 31. The exhibition includes a representative collection of scientific instruments of the kind to be used during the International Geophysical Year. Earth satellites, high-altitude rockets, the weather, earthquakes, and the earth's magnetic field are among the topics illustrated, less familiar subjects represented including the aurora, solar flares, cosmic rays, glaciology, and oceanography. An illustrated handbook, which is being published in conjunction with the exhibition, presents a general account of the phenomena to be studied and the observations to be made during the International Geophysical Year.

OBITUARY.—We record with regret the death of Mr. Thomas Thomson, at the age of seventy-six, on April 16. Mr. Thomson was chief engineer at the Appleby-Frodingham Works, Scunthorpe, until 1930, when he joined H. A. Brassert and Co., Ltd., as director and chief engineer. He was in charge of the reconstruction of the Irlam Works of the Lancashire Steel Corporation, Ltd., the construction of the Corby Works of Stewarts and Lloyds, Ltd., and the reconstruction of the Ebbw Vale Works of Richard Thomas, Ltd. He joined John Miles and Partners (London), Ltd., on its formation in 1945, and was engaged in the replanning of some of the major steel works on the Continent. We also note with regret the death of Mr. Ronald Whale, mechanical engineer, of John Miles and Partners (London), Ltd., which occured on April 12 at the age of thirty-four.

ENGINE ENDURANCE.—A small internal combustion engine built by B.S.A. Motor Cycles, Ltd., recently carried out four weeks' continuous running, followed by a strip inspection. Since the engine was running on tractor vaporising oil and lubricated with straight mineral oil, the trial was by no means favourable to the engine. An air-cooled side-valve, single-cylinder engine of 420 c.c. was used, developing 5¼ h.p. at 2800 r.p.m., corresponding to 58 lb per square inch b.m.e.p., approximately 75 per cent full power. The fuel and oil consumptions were rather under 4½ pints and 1 oz per hour, respectively. The engine was stopped only for two or three minutes every twenty-four hours for 689 hours. Stripping of the engine showed that decarbonisation and grinding of the exhaust valve were needed. Wear amounted to 0·001in on the bore, 0·0005in on the crank-pin, and 0·0007in on the drive side main bearing journal. The main bearing liners had reached worn limits. The wear is attributed to abrasive dust from the concrete floor on which the engine ran.

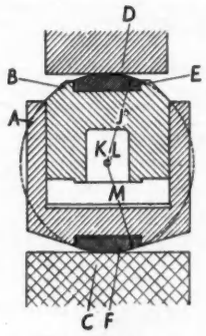
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

HYDRAULIC MACHINERY

771,694. July 28, 1954.—LIFTING DEVICES, Maschinenfabrik Augsburg-Nurnberg A.G., Nurnberg, Germany.

For lifting heavy loads with a small to medium height of lift it is the usual practice to use a device comprising hydraulic or pneumatic lifting gear operating with a piston moving in a cylinder, and having opposed end surfaces, one of which rests on



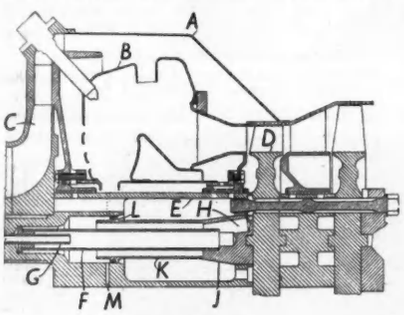
No. 771,694

the ground while the other engages the load. The drawing shows a lifting device according to the invention, which works on the hydraulic principle. The lifting device consists substantially of a cylinder *A* and a piston *B*. The cylinder rests on the support *C* and the piston *B* lifts the load *D* as it rises. At the side of the piston facing the load *D* there is an insertion *E* and at the side of the cylinder facing the support *C* is a further insertion *F*, both insertions being replaceable. For reducing the coefficient of rolling friction the insertions *E* and *F* are made of hardened steel. The surfaces of the insertions which come in contact with the load and the support respectively, have the form of spherical segments, with the same radii *J*. When the piston has reached the position shown in the drawing, the centres of curvature *K*, *L* of the spherical segments come together in one point. On the load *D* being moved sideways, the lifting device, consisting of the cylinder *A* and the piston *B*, rolls in the manner of a ball with the centre *K*, *L* and the diameter *M* on the support *C*. The line of force of the load *D* passes in each position of the lifting device through the centre *K*, *L*, and moments do not occur in the lifting device, but only vertical forces act on the piston *B* and horizontal forces on the cylinder wall. —*April* 3, 1957.

GAS TURBINES

772,165. June 16, 1955.—GAS TURBINE ENGINES, Blackburn and General Aircraft, Ltd., Brough, East Yorkshire. (*Inventor: Francis Robert Bell.*)

This invention relates to improvements in gas turbine engines and is concerned with such engines having an annular combustion chamber into which fuel is projected radially, such as that described in



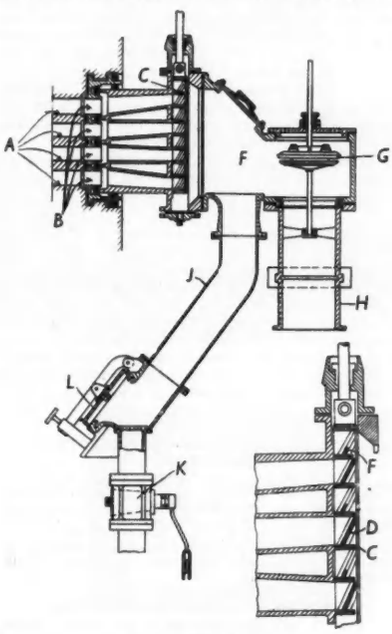
No. 722,165

Specification No. 686,908. The type of engine illustrated in the drawing comprises stationary outer casing *A*, containing an annular combustion chamber *B*, with a compressor *C* at the front and a turbine disc *D* at the rear interconnected by a rotor shaft *E*. According to the invention, the rotor shaft *E* is hollow and contains a tube *F*, the forward end of which embraces a fuel delivery pipe *G*, whilst its rear end opens into bores *H* in a part *J* in intimate heat transfer contact with the core of the turbine disc *D*. The part *J* extends forwards as a tube *K* between which and the outer wall of the shaft *E* is a seal *L*. Radial bores *M* through the wall of the shaft *E* open into the combustion chamber *B*. In this arrangement fuel under pressure from the pipe *G* passes along the tube *F* to discharge into the bores *H* to wipe the walls, which action is assisted by the centrifugal action of the rotating parts. The fuel then passes from the bores *H* and along the tube *K* in counter-current to the flow tube *F*, and finally passes through the radial bores to enter the combustion chamber *B*. The fuel, in wiping the walls of the bores *H*, extracts heat so reducing the temperature of the core of the turbine disc, and it becomes preheated to a degree which may even be sufficient to convert it to a vaporised state. There is thus achieved the desired cooling of the core of the turbine disc with at the same time desirable preheating of the fuel prior to its entry into the combustion chamber.—*April* 10, 1957.

FURNACES AND OVENS

772,687. January 27, 1955.—REGENERATIVELY HEATED INDUSTRIAL OVENS, Didier-Kogag-Hinselmann G.m.b.H., 66, Rüttenscheider Strasse, Essen, Germany.

The invention relates particularly to coke ovens heated alternatively with rich gas or with lean gas. The drawing shows a cross section through a horizontal inlet channel arrangement for one regenerator. The horizontal channel is divided into several individual horizontal channels *A* that are directed to individual regenerator cells. In front of the horizontal inlet channel nozzles *B* of the regenerator is disposed a controlling device *C*, which distributes the flowing medium to the horizontal inlet channels of the regenerator. For each nozzle (see the lower view) the device *C* has two compartments, one of which is closed by a deep plate *D*, and the other contains a shallower plate *E*, the depth of which adjusts the size of the aperture for the passage of air or lean gas when the compartment is brought into register with one of the nozzles by moving the device by the height of one compartment. An exhaust heat valve housing *F* with valve member *G* and lower valve body *H* is



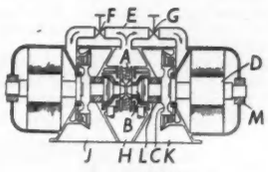
No. 772,687

arranged in front of the control device *C*. An inlet pipe *J* discharges into the valve housing *F* and is connected at its lower end to an inlet housing for the introduction of lean gas, with an inlet valve *K* for the lean gas and above a flap valve *L* for the alternative introduction of air into the same inlet pipe. By these provisions, the same direction of flow of air or lean gas always takes place in front of the inlet channels, independently of whether the heating is with rich gas or with lean gas. Consequently, a similar application of air or lean gas to the separate regenerators takes place, independently of the kind of heating. The result is an improvement in the operation of the heat-exchange and combustion.—*April* 17, 1957.

STEAM AND GAS TURBINES

772,688. February 28, 1955.—CONTRA ROTATION RADIAL FLOW TURBINE, Svenska Turbinfabriks Aktiebolaget Ljungström, of Finspong, Sweden.

The invention relates to contra rotation radial flow turbines used for driving electric generators, and is characterised, chiefly, by the fact that there is provided between each generator and the associated turbine disc a single shaft journal bearing only. In the drawing *A* indicates an overhung radial flow turbine disc carried by a shaft *B*. *C* is another turbine disc supporting blades for axial flow. This disc is provided on its side facing the radial flow blading with a shaft member formed integrally with the turbine disc, and this shaft is bolted to the shaft of the radial flow disc. On its other side the turbine disc



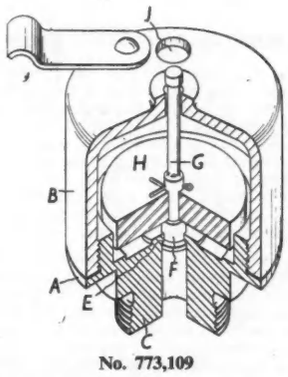
No. 772,688

C is bolted to a shaft supporting the rotor *D* of an electric generator. The driving fluid discharged from the radial flow blading passes through conduits *E* to the axial flow turbine sections, and thence to one or more condensers, not shown. Inserted in the conduits are valves *F* and *G*, by means of which the admission of driving fluid to one or both axial flow turbine sections may be interrupted. The turbine unit described is well suited for steam turbines where the driving fluid delivered from the outlet *H* is passed to a condenser in which, with the valves *F* and *G* closed, hot water is produced by steam exhausted from the turbine, while with the valves open the outlets *J* and *K* lead to condensers containing cold cooling water and a high vacuum in order that a maximum fall in pressure may result in the turbine. In the condenser fed with steam from the outlets *J* and *K* the temperature is held as low as possible in order that the turbine may yield the maximum power output. The shaft system supporting the electric rotor and the turbine discs *A* and *C* is mounted in two shaft journal bearings *L* and *M*, of which the bearing *L* only is positioned between the turbine discs. By this means the difficulty of adjusting the shaft system with respect to three bearings is avoided. By making the turbine disc *C* solid and interposing it as shown between the turbine shaft and the rotor shaft, it will get a high degree of resistivity to stresses. —*April* 17, 1957.

LUBRICATING DEVICES

773,109. June 23, 1955.—DRIP FEED LUBRICATORS, Sentinel (Shrewsbury), Ltd., Whitchurch Road, Shrewsbury, and Wilfred George Ind, of the Company's address.

As will be seen, the cylindrical chamber of the lubricator is formed with a flat disc-like base *A*, on to which screws an inverted cup-shaped cover *B*. The underside of the base is formed with a central screwed union *C* for the connection of an oil pipe. The bore of this union has a reduction in diameter near its upper end to form the seating *E* for an inverted poppet valve *F*, of which the stem *G* extends up through an aperture in the top cover of the chamber. This aperture is of appreciably greater diameter than



No. 773,109

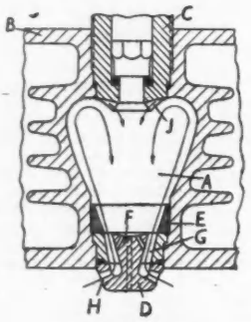
the stem of the valve, so that the latter is permitted a limited amount of lateral oscillating movement. A thick disc-shaped float *H* of plastic, smaller in diameter than the inside of the chamber, fits over the valve stem and is held in position near its lower end by a split pin holding it against a shoulder on the stem. A filling aperture *J* is provided in the top cover and is closed by a pivoted metal strip to keep out foreign matter. With the lubricator full, the float will urge the valve upwards against its seating under static conditions and prevent the escape of lubricant. When the lubricator is subjected to continuous vibration, however, the float and valve assembly oscillates so that the valve is partially unseated and allows lubricant

to flow slowly, but continuously, to the bearing. To provide lubrication prior to starting up, the top end of the valve stem, which projects through the cover, is depressed for a few moments. The float and valve assembly falls slightly when the lubricator is empty to indicate the lubricator needs replenishment.—*April* 24, 1957.

INTERNAL COMBUSTION ENGINES

773,278. August 16, 1955.—DIESEL ENGINES HAVING A PRECOMBUSTION CHAMBER, Maschinenfabrik Augsburg-Nurnberg A.G., Stadtbachstrasse 7, Augsburg 2, Germany.

The invention relates to a diesel engine having a precombustion chamber with a perforated insert, separating the precombustion chamber from the combustion chamber. As can be seen from the



No. 773,278

drawing, a precombustion chamber *A* is in one piece with a cylinder head *B*, or the chamber can be fitted in the cylinder head in known manner. The precombustion chamber is bounded at its upper end by a fuel injection nozzle *C* and at its lower end by an insert *D*, which is retained in position by a threaded ring *E*. A conical deflector *F* is fitted within the insert and the inner wall is substantially funnel-shaped, so that a conical annular gap *G* is formed between the deflector and the wall of the insert. The insert has nozzle-like bores *H* which are substantially tangential to the inner wall, the entering air being deflected by the deflector *F* out along the inner wall of the precombustion chamber. The internal face of the threaded ring *E*, which secures the insert *D*, is also of conical form, so that a smooth transition to the pear-shaped precombustion chamber is produced. The rounding of the top of the precombustion chamber serves to deflect, through substantially 180 deg., the combustion air flowing in along the wall of the chamber, and this air, after deflection, proceeds in the same direction as the stream of injected fuel. In order that some of the air may be mixed with the fuel, the portion of the fuel injection nozzle projecting into the top of the precombustion chamber is provided with radial slots *J* through which combustion air can pass to penetrate into the central portion of the fuel stream. A modified design is also described in the specification.—*April* 24, 1957.

Launches and Trial Trips

DARWIN, passenger and cargo ship; built by the Goole Shipbuilding and Repairing Company, Ltd., for the Falkland Islands Company, Ltd.; length between perpendiculars 220ft, breadth moulded 40ft, depth moulded to main deck 17ft 6in, gross tonnage 1700, deadweight 1050 tons on draught of 13ft 6in, bale capacity of holds 40,000 cubic feet; thirty six passengers; three holds; triple expansion engine, 1150 i.h.p. at 125 r.p.m., steam supplied by two marine return tube boilers. Launch, February 18.

ARABIAN GULF, oil tanker; built by the Furness Shipbuilding Company, Ltd., for the Afran Transport Company of Liberia; length overall 661ft 7in, length between perpendiculars 630ft, breadth moulded 87ft, depth moulded, 45ft 6in, deadweight 31,925 tons on 34ft 2½in summer draught; thirty oil cargo compartments, one main cargo pump room, four 4500 U.S. gallons per minute, centrifugal turbine-driven pumps and four 150 tons per hour vertical reciprocating stripping pumps, cargo main 13½in bore, tank suctions 12in bore; two 500kW, 450V, three-phase, 60 c/s turbine-driven alternators, one 100kW diesel-driven alternator; one set of Richardsons Westgarth double reduction geared turbines, 12,500 normal s.h.p. at 105 propeller r.p.m., 13,750 maximum s.h.p. at 108 propeller r.p.m., two Foster Wheeler "D" boilers supply steam at 600 lb per square inch and 850 deg. Fah. Trial, February 21.

CANADIAN STAR, cargo liner; built by the Caledon Shipbuilding and Engineering Company, Ltd., for the Blue Star Line, Ltd.; length overall 473ft 3in, breadth moulded 63ft, depth moulded to shelter deck 39ft 6in, deadweight 9460 tons in open shelter deck condition, sea speed 15½ knots; twelve passengers; five holds; one 50-ton, six 10-ton and ten 5-ton derricks, electric winches, Macgregor steel hatch covers; four 200kW diesel-driven generators; two Cochran auxiliary boilers, one Scott-Doxford oil engine of 8000 b.h.p. Trial, February 21 and 22.

CLOVELLA, trawler; built by John Lewis and Sons, Ltd., for the Clova Fishing Company, Ltd.; length overall 122ft, breadth 24ft, depth 11ft 6in, gross tonnage 220, fish room 5500 cubic feet; 100 b.h.p. trawl winch of 800 fathoms of 2¾ warp barrel capacity, powered by an 82½kW generator driven by a 157 b.h.p. diesel engine; two 20kW diesel-driven generators; British Polar Mark M.44 M. diesel engine, 640 b.h.p. at 250 r.p.m. Trial, February 21.

CHANGUINOLA, refrigerated banana cargo and passenger liner; built by Alexander Stephen and Sons, Ltd., for Elders and Fyffes, Ltd.; length between perpendiculars 390ft, breadth moulded 56ft 6in, depth to upper deck 35ft; twelve passengers; fourteen insulated cargo spaces, two eight-cylinder "Arcton 6" compressors, eight 5-ton derricks; two 450kW turbine-driven generators; one 400kW diesel-driven generator, and one 60kW emergency generator; one set of double reduction geared, compound turbines take steam at 500 lb per square inch and 790 deg. Fah. from two Babcock and Wilcox sectional header single-pass boilers. Launch, February 28.

CLOVERBANK, cargo liner; built by Harland and Wolff, Ltd., at Belfast, for the Andrew Weir Shipping and Trading Company, Ltd.; length overall 483ft, length between perpendiculars 450ft, breadth moulded 62ft 6in, depth moulded to upper deck 38ft 6in, gross tonnage 6450; nine watertight compartments, five main holds, one 25-ton, two 10-ton, twelve 5-ton and two 3-ton derricks, electric cargo winches; three 175kW diesel-driven generators; Harland and Wolff two-stroke, single-acting, opposed-piston diesel engine, six cylinders, 620mm diameter by 1870mm combined stroke. Trial, March 11.

RUYSDAEL, cargo ship; built by Smith's Dock Company, Ltd., for the Bolton Steam Shipping Company, Ltd.; length between perpendiculars 435ft, breadth moulded 60ft 3in, depth moulded to upper deck 38ft 9in, deadweight 10,000 tons on 26ft 6in draught, service speed 13½ knots; five main cargo holds, three "Bipod" masts, ten 5-ton derricks, steam winches; one 75kW steam-driven generator and one 75kW diesel-driven generator, two Scotch marine boilers, Hawthorn-Doxford opposed-piston, two-stroke diaphragm oil engine, four cylinders, 670mm diameter by 2320mm combined stroke, 4450 b.h.p. at 115 r.p.m. Launch, March 15.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Thurs., May 23.—KENT BRANCH: Royal Star Hotel, Maidstone, Annual General Meeting, 7.30 p.m. ★ SOUTHAMPTON BRANCH: Polygon Hotel, Southampton, "Sound Recording on Tape and Disc," J. F. Doust, 8 p.m.

Sat., May 25.—OXFORD, READING AND DISTRICTS BRANCH: Collier Lecture Room, Regent's Park College, Pusey Street, Oxford, "Applications of the Cathode-Ray Tube," C. H. Gardner, 6.30 p.m.

BRITISH INSTITUTE OF MANAGEMENT

Wed., May 22.—Management House, 8, Hill Street, London, W.1, "Planning Wide Range Production for Fluctuating Demand," T. P. Child, 6.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., May 22.—LONDON MEETING: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Barium Titanate and its Use as a Storage Device," G. Campbell, 6.30 p.m.

BRITISH INTERPLANETARY SOCIETY

Sat., May 18.—LONDON MEETING: Caxton Hall, Caxton Street, Westminster, London, S.W.1, Annual General Meeting, 6 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Wed., May 29.—N. REGION: Grand Hotel, Sheffield, "The Production of Fuel Oils: Their Delivery, Storage and Preparation for Burning," T. Marsden, 11 a.m.; "Fuel Oil Firing for Furnace Work," T. Chippindale, 2.15 p.m.

INCORPORATED PLANT ENGINEERS

Fri., May 31.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Problems," 7.30 p.m.

INSTITUTE OF FUEL

Wed., May 29.—LONDON MEETING: Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "Some Fuel Developments in the U.S.A.," F. F. Ross, 5.30 p.m.

INSTITUTE OF NAVIGATION

To-day, May 17.—LONDON MEETING: Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Navigation and the Airlines," E. W. Pike, 5.15 p.m.

INSTITUTE OF PETROLEUM

Wed. to Sat., May 29 *to June* 1.—Grand Hotel, Folkestone, Summer Meeting.

INSTITUTION OF CHEMICAL ENGINEERS

Tues. to Wed., May 28 *to* 29.—Church House, Westminster, London, S.W.1, Joint Symposium on "The Scaling-Up of Chemical Plant and Processes."

INSTITUTION OF CIVIL ENGINEERS

Tues., May 21.—STRUCTURAL AND BUILDING (B) MEETING: Great George Street, Westminster, London, S.W.1, "Brick and Masonry Arch Bridges: An Investigation," C. S. Chettoe and William Henderson, 5.30 p.m.

Tues., May 28.—WORKS CONSTRUCTION (B) MEETING: Great George Street, Westminster, London, S.W.1, "Portishead 'B' Power Station, with particular reference to the Circulating Water Works," H. D. Morgan and Louis Sancha, 5.30 p.m.

Thurs., May 30.—MARITIME AND WATERWAYS (B) MEETING: Great George Street, Westminster, London, S.W.1, "The Regimen of the Thames Estuary as Affected by Currents, Salinity, and River Flow," Sir Claude Inglis and F. H. Allen 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Sat., May 18.—RADIO AND TELECOMMUNICATION SECTION: Visit to B.B.C. and I.T.A. Television Transmitting Stations, 9.15 a.m.

Mon., May 20.—LONDON MEETING: Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, Joint Meeting with the Institutions of Civil and Mechanical Engineers, Discussion on the "Report on the Development of Hydro-Electric Power in the Soviet Union," 5.30 p.m. ★ LONDON GRADUATE AND STUDENT SECTION: Savoy Place, London, W.C.2, Annual General Meeting, 6.30 p.m.

Wed., May 22.—SUPPLY SECTION: Savoy Place, London, W.C.2, "Voltage Performance of Series Capacitors in Transmission and Distribution Lines," J. M. Magowan, 5.30 p.m.

Thurs., May 23.—Savoy Place, London, W.C.2, Annual General Meeting, 5.30 p.m., followed by "General Applications of Digital Computers," A. D. Booth, 6.30 p.m.

Fri. to Mon., May 24 *to* 27.—SCOTTISH CENTRE: Pitlochry Hydro Hotel, Pitlochry, Spring Meeting.

Wed., May 29.—SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Annual General Meeting, followed by "The Ailt-na-Lairige Prestressed Concrete Dam," J. A. Banks, 7 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Fri., May 24.—Crown Hotel, Clayton Street, Newcastle upon Tyne, Annual General Meeting, 6.15 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, May 17.—GENERAL MEETING IN CONJUNCTION WITH THE LUBRICATION AND INTERNAL COMBUSTION ENGINE GROUPS: 1, Birdcage Walk, Westminster, London, S.W.1, "Diesel Engine Lubricants: Their Selection and Utilisation, with Particular Reference to Oil Alkalinity," A. Dyson, L. J. Richards and K. R. Williams, 6 p.m.

Sat., May 18.—LONDON GRADUATES' SECTION: Visit to the Generating Plant at Bankside Power Station, 9.30 a.m.

Mon., May 20.—JOINT MEETING WITH THE INSTITUTIONS OF CIVIL AND ELECTRICAL ENGINEERS: Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, Report on "Hydro-Electric Projects in the U.S.S.R.," 5.30 p.m. ★ MIDLAND GRADUATES' SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, Annual General Meeting, followed by "Gas Turbines," R. H. Ashton, 6.45 p.m.

Tues., May 21.—S. WALES BRANCH: South Wales Institute of Engineers, Park Place, Cardiff, Report on "Engineering Education in the U.S.S.R.," 6.15 p.m.

INSTITUTION OF NAVAL ARCHITECTS AND INSTITUTE OF MARINE ENGINEERS

Sat., May 18.—S. JOINT BRANCH: Visit to Saunders-Roe, Ltd., Cowes, Isle of Wight.

INSTITUTION OF PRODUCTION ENGINEERS

Wed., May 22.—MIDLANDS REGION: Botanical Gardens, Edgbaston, Birmingham, Regional Day Conference, "Tooling—Tomorrow's Production," H. Burke.

INSTITUTION OF PUBLIC HEALTH ENGINEERS

Tues., May 21.—Caxton Hall, Caxton Street, Westminster, London, S.W.1, Joint Meeting with the Society for Water Treatment and Examination, "Treatment and Examination of Water," W. Gordon Carey, 6 p.m.

INSTITUTION OF WATER ENGINEERS

Wed. to Fri., May 22 *to* 24.—Grand Atlantic Hotel, Weston-super-Mare, Sixty-Second Summer General Meeting.

ROYAL AERONAUTICAL SOCIETY

Tues., May 28.—SECTION LECTURE: 4, Hamilton Place, London, W.1, "Flight Instruments," F. W. Meredith, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., May 27.—12, Great George Street, Westminster, London, S.W.1, Annual General Meeting, 5 p.m.

ROYAL METEOROLOGICAL SOCIETY

Thurs. to Fri., May 23 *to* 24.—JOINT SYMPOSIA WITH THE ROYAL ASTRONOMICAL SOCIETY: Royal Astronomical Society, Burlington House, Piccadilly, London, W.1, "Planetary Atmospheres and Convection in Rotating Fluids."

SOCIETY OF INDUSTRIAL RADIOLOGY

Fri., May 24.—LONDON MEETING: British Institute of Radiology, 32, Welbeck Street, London, W.1, "Investment Castings and Their Inspection," Mr. Tomkinson, 7 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Tues., May 28.—Manson House, Portland Place, London, W.1, Annual General Meeting, 6 p.m.

SOCIETY FOR WATER TREATMENT AND EXAMINATION

Tues., May 21.—Caxton Hall, Caxton Street, Westminster, London, S.W.1, Joint Meeting with the Institution of Public Health Engineers, "The Chemist and the Public Health Engineer in Relation to Water Treatment and Examination," W. G. Carey, 6 p.m.